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AGM-69A SRAM EXPLOSIVE COMPONENTS SURVEILLANCE PROGRAM SUMMARY REPORT AND FY74 SERVICE LIFE ESTIMATE

Charles E. Stanbery, et al

Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio

January 1975

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TECHNICAL REPORT ASD—TR—75—4

JANUARY 1975

AERCNAUTICAL SYSTEMS DIVISION
AGM—69 SRAM SYSTEM PROGRAM OFFICE
AIR FORCE SYSTEMS COMMAND
WRIGHT—PATTERSON AIR FORCE BASE, OHIO 45433

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13. ABSTRACT
Service life estimates for the SRAM rocket motor and ordnance devices are contained in this document as derived from the SRAM Explosive Component Surveillance Program conducted by the Ogden Air Logistics Center. Results of the initial survey are scheduled for publication in Fiscal Year 1974, and annually thereafter. The purpose of this document is to present the life expectancy of components to allow orderly replacement of aged-out components with minimum impact on weapon system operational capability and give a overall surveillance program summary report thru November 1974. This report is consists of two Volumes. Volume I contains the SRAM Surveillance Program Summary Report and the FY74 SRAM Service Life Estimate. Volume II consists of three appendices on the SRAM Service Life estimate procedures, Rocket Motor and explosive components.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Rocket Motor						
Instrumented Motor						
Ordnance Devices						
Explosive Components						
Service Life Estimate						
Ogden Air Logistics Center						
Regression						
Attribute						
AGE-out						
AGE Life						
Explosive						
SSPWG						
Working Group						
Dissection						
AGE Sensitive Item						
Failure Criteria						
Estimates						
Procedures						
Propellant						
Solid-Propellant Rocket Motors						
Short-Range Ballistic Missiles						
Air-To-Surface Missile						
Testing						
Structural/Mechanical Design						

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FOREWORD

The AGM-69A Short Range Attack Missile (SRAM), System Program Office established an Explosive Components Aging and Surveillance Program in April 1971. The Program is being conducted by the Airmunitions IM Division of Ogden Air Logistics Center, Hill AFB, Utah 84001. The Surveillance Program is currently managed by the SRAM PO, (YS69E), Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson AFB, Ohio 45433. Maj. Charles E. Stanbery, YS69EA is the SRAM Surveillance Program Manager. Capt. Lester L. Lyles, YS69EJ is the SRAM Rocket Propulsion Engineer.

Contracts were established iwth the SRAM prime contractor (The Boeing Company, Seattle, Washington), and the rocket motor subcontractor (Lockheed Propulsion Company, Redlands, California), to provide Special Test Equipment, tooling, training and technical support to the personnel at Hill AFB. The Boeing contract numbers are F33657-71-C-0918 and F33657-73-C-0734 and the Lockheed contract is F33657-72-C-1103, beginning in June 1972. Tests and research conducted to establish the first SRAM Service Life Estimate began in May 1973 and concluded in November 1974. This report was submitted in February 1975.

This report contains no classified information extracted from other classified documents

This technical report has been reviewed and is approved.

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ABSTRACT

The SRAM Explosive Component Surveillance Program is structured to provide the necessary data on aging characteristics of the SRAM rocket motor and ordnance devices. The data obtained from the series of tests conducted on the motor and ordnance devices were analyzed to allow a prediction of the component's age-life. During each year of the Surveillance Program, five (5) rocket motors extracted from missiles in the SAC field inventory are to be static fired. Two (2) rocket motors from the field inventory are to be chemically dissected annually to allow physical/ballistic property tests on the motor propellant. Twenty-two (22) of the ordnance devices (Missile Ejector Cartridge, Fin Unlock Squib, Igniter Pressure Cartridge, Battery Gas Generator Squib, Battery, and Electrical Cable Switch Assembly) are to be tested each year. This year, five field motors ranging in age from 639 days to 817 days old, and in flight hours from 49 hours to 195 hours, successfully completed dissection and propellant testing in time to support this Service Life Estimate. Testing of the ordnance devices also had not been accomplished in time to generate Service Life Estimates for the respective devices. The static firing regression analyses for the rocket motor indicate some small aging trends: Results indicated with an 81% Confidence Level, that 90% of the motors in the SAC inventory will not age-out prior to the design service life of 5 years. The dissection regression analyses did not alter the conclusions reached from the static firings. However, it did raise questions about the aging trends of the motor propellant stress/strain capabilities. As a result of the tests accomplished this year and the analyses conducted, it is recommended that the SRAM Explosive Component Surveillance Program continue as planned for the coming year. It is further recommended that stronger emphasis be placed on the motor dissection program with the purpose of resolving the concerns/questions raised by the one dissection conducted this year.

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LIST OF ABBREVIATIONS, SYMBOLS AND TERMS

AFLC - Air Force Logistics Command

AFRPL - Air Force Rocket Propulsion Laboratory

AFSC - Air Force Systems Command

AFSPO - Air Force SRAM Project Office

AGE-OUT - Point at which any motor/Component perforamnce parameter reaches its failure limit or degradation is to extent that required functional reliability is no longer met.

Age-Sensitive Item - Item whose function may be impaired due to aging under operational conditions.

AGM-69A - Air to Ground Missile # 69A (SRAM)

AHS # - Official A. F. Serial number for SRAM motors (AHS-0001, -0002, etc.)

ALC - Air Logistics Center (formerly Air Material Area)

ASD - Aeronautical Systems Division

ASIA - Age-sensitive item assessment

ATP - Acceptance test procedure

BATCHMATES - Motors cast from the same propellant batch (Initially 2 motors per batch, now 3 motors)

BIAXIAL STRAIN - Physical Property measured by applying tensile forces in opposite directions on a propellant sample to get multiaxial stress/strain

BOND PADS - Cup elliptical areas bonded in three places circumferentially around the motor case

BOOST CUP - First "bag" of propellant for the SRAM 2 pulse motor

BURN-RATE - Rate at which the propellant surface burns, in inches/sec. Ranges from 1.85 at -65°F to 2.73 at 145°F for the SRAM motor

Critical Age-Sensitive Item - An item which because of age degradation may fail to perform its intended function and could result in a critical failure of the subsystem.

DAGE - Depot aerospace ground equipment

DAR - Data Automation Requirement

DDT&E - The developmental phase for the SRAM, from 1966 to the start of Qualification in 1971 (Design, development, test and evaluation)

DISSECTION - Method of physically/chemically cutting away a motor case to expose the propellant for testing

DR - Dynamic resistance

DSL - Demonstrated Storage Life - Age of the oldest subsystem, component or subassembly that has been successfully demonstrated by at least one full-scale performance test.

EED - Electro-explosive device

EMI - Electromagnetic Interference

ETA - Explosive transfer assembly

EXTERNAL CARRIES - Carries on external pylons on the B-52/FB-111 aircraft

Failure Limit - That value of a functional parameter which constitutes a true limit of the acceptable operating range with zero margin of safety.

Failure Mode - Physical description of manner in which a failure occurs under specified conditions.

F_{AVG} - Average thrust, average sea level thrust over action time (lbs.)

FCAA - Flight control actuation assembly

FLIGHT HOURS - Number of total hours flown on the carrier aircraft

G.A.T. - Group Acceptance Test motor fired at Lockheed to qualify or accept several rocket motors for delivery to the government

GCU - Guidance and control unit

GROUP - Motors from several propellant batches arranged together for purpose of selecting a GAT and subsequent government acceptance

INSTRUMENTED MOTOR - Special surveillance motors cast with internal gages

IPCA - Igniter pressure cartridge

I_T - Impulse, integral of sea level thrust over action time (lb-sec)

J.A.N.N.A.F. - Joint, Army, Navy, NASA, Air Force Chemical Propulsion Society

LAT - Lot acceptance test

LATP - Lot acceptance test procedure

LINER - Material used to line the motor cups prior to casting propellant in them. Acts as an adhesive interface between rubber cups and propellant

L.P.C. - Lockheed Propulsion Company; designer, builder of the SRAM motor

LSC - Linear shaped charge

LUGWELL - Two well areas on top of motor which hold the clevis' needed to support/lift the motor

MI&RP - Missile inspection and receiving report

MOUSEHOLE - Pressure Differential Section

OEA - Ordnance Engineering Associates, Des Plaines, Illinois

Ogden ALC - Ogden Air Logistics Center (formerly OOAMA Ogden Air Materiel Area)

Oklahoma City ALC - Oklahoma City Air Logistics Center (formerly OCAMA Oklahoma City Air Materiel Area)

OT&E - Operational Test and Evaluation launches performed by SAC crews

OTL - Operational test launches performed by SAC crews

PFRT - Preliminary flight rating test

PMAX - Maximum pressure, maximum instantaneous chamber pressure (psia)

RACEWAY RAILS - Metal rails running longitudinally along the motor case, which house electrical harness, lugwells, etc.

RACETRACK - Raised rubber ridge at perimeter of elliptical cup bond pads for stress relief

RATTAIL - Sustain Igniter Initiator Lead Wire Assembly

REGRESSION ANALYSIS - Method of statistically analyzing data to determine degradation trends

RTV - Room Temperature Vulcanizing

S/A - Safe/arm

SAC - Strategic Air Command

San Antonio ALC - San Antonio Air Logistic Center (formerly SAAMA San Antonio Air Materiel Area)

SHORE "A" - Hardness measurement on surface of propellant

SHORT GRAINS - Special truncated grains of propellant built to simulate first portion of either boost or sustain grains

SIS - Separation Ignition Switch

SLE - Service Life Estimate - A quantitative assessment of the hardware minimum life that can be expected under operational conditions before age degradation results in unacceptable reliability.

Specification Limit - The maximum or minimum value of a functional parameter allowed by the applicable procurement specification, which allows a certain safety margin.

SPO - Systems Program Office

SPTE - Special Propellant Test Equipment

SRA - Special Repair Area

SRAM - Short Range Attack Missile

SRAMISM - SRAM Instrumented Surveillance Motor

SSPWG - SRAM surveillance program working gorup

STAR - Select, Test, Analyze and Report Program

STE - Special test equipment

SUSTAIN CUP - Second "bag" of propellant in SRAM 2 pulse motor

t_{ACT} - Action time, time interval from 10% of maximum chamber pressure following grain ignition to 10% of maximum pressure preceding motor extinguishment (sec)

TAM's - Special Take-Apart Motors, built with metal cases that can be readily segmented to gain access to the propellant

TBC - The Boeing Company, prime contractor for the SRAM missile

t_{BURN} - Burn time, time interval from 10% of chamber pressure at two seconds to sharp pressure drop at motor extinguishment. The latter point is determined as follows: Tangents are drewn to the descending portion and to the level portion of the curve. The angle between the two tangents is bisected by a line extended to the curve. A line parallel to the pressure axis is drawn from the intersection of the bisector and the curve to the time axis. The time so indicated is the end of burn time.

TCLE - Thermal Coefficient of Linear Expansion

t_{END} - End time, time interval from ignition signal to end of action time (sec)

t_{DECAY} - Thrust decay time, time interval from end of burn time (Reference 1.0-1, Section 12.0) to end of action time (sec)

t_{DELAY} - Ignition delay time, time interval from the ignition signal to generation of a pressure equal to ten percent of the motor pressure at two (2) seconds.

THIOKOL - Thiokol Corp., Brigham City, Utah. Participated in second source qualification in 1972-73. Failed two qual motors out of 15 fired.

t_{IGN} - Ignition time, time interval from ignition signal to 75% of the pressure at 2 seconds.

t_{RISE} - Ignition Rise time, time interval for pressure to rise from 10% of chamber pressure at 2 seconds to 75% of chamber pressure at 2 seconds.

t_{START} - Start time, time interval from ignition signal to 1100 psi (sec)

UNIAXIAL STRAIN - Physical property measurement, attained by holding one end of propellant sample rigid and applying tensile force at opposite end

SECTION I.

INTRODUCTION

1.1 INTRODUCTION

The SRAM Explosive Component Surveillance Program was structured to meet the requirements of AFR 136-6 "Conventional Munitions Quality Assurance" and to provide necessary data on the aging characteristics of the SRAM rocket motor and the other ordnance devices in the SRAM Missile System. The data obtained from an economical series of surveillance tests conducted on the motor and ordnance devices, were analyzed to allow a prediction of component age-life or make a service life prediction that could provide timely replacement/retrofit information. This paper will discuss primarily the SRAM Missile System Service Life Prediction technology and capabilities and present the FY 74 Service Life Estimate for the SRAM Explosive Components.

The yearly Service Life Estimate is made by a joint AFSC, AFLC, AFRPL and Contractor team comprised to form the SRAM Surveillance Program Working Group. Data are obtained from testing of chronologically and service aged hardware from SAC bases; from special test components such as Take-Apart Motors and Instrumented Motors; from manufacturer Lot/Group Acceptance Test data (zero-time data); from SAC OT&E missile launches; and from the San Antonio Air Logistics Center Service Star Program. With the exception of the manufacturers zero-time acceptance tests, and the OT&E launches, all of the testing is conducted at the Ogden Air Logistics Center, Hill AFB, Utah. The tests are conducted in accordance with Reference (3), SRAM Explosive Component Surveillance Program - Implementation Plan.

Service life estimates for the SRAM System Motor/Components were performed utilizing flight data from the missile operational test program, component test data, and dissection and static fire data from returned field experience motors/components tested physically and ballistically at Hill AFB, Utah. Computerized Data Storage, Retrieval and Analysis Techniques were adapted from the Minuteman program to incorporate the SRAM system additional requirements. Analytical techniques were developed to combine motor/component data covering a temperature range of -65 to +145°F which is beyond the benign Minuteman environment. The service life estimate was separately determined for the following measures of aging or motor age-life: calendar age, number of external carries, total number of flight carries, flight hours below 15,000 feet and total flight hours. This age-life technique provides the capability to utilize the "Lead the Fleet" techniques for motor/component age out determination, fleet retrofit/replacement, or usage limitations if required.

The procedures used for making the first service life estimate for the SRAM motor/components (June 1974) are extensions of Minuteman procedures/techniques which were modified to accommodate features unique of the SRAM weapon system, such as:

(1) A two-pulse motor technology vs. one-pulse.

(2) Intermittent air-carry operations with resultant dynamic loading vs. static storage in a ground emplacement.

(3) Ready-alert and captive flight exposure to prevailing weather conditions vs. the physical and thermal protection of the Minuteman silo.

Exposure to these conditions introduces several aging measures in addition to simple "calendar time." As a result, SRAM surveillance procedures differ from existing procedures primarily in the collection and analysis of motor/component data and SAC maintenance and utilization data. As the surveillance program develops, differences in other areas of the surveillance program are anticipated. A general description of the collection and analysis of SRAM motor/component data is presented here. Technical details are reported in References 7 thru 15.

The major goals in the treatment of the motor/component data were to extend the lead time for a possible motor/component replacement program and to minimize the surveillance program costs by yearly testing only a small number of motors/components. The several methods used to achieve these goals are: (1) test motors/components which lead the fleet in age, (2) use data obtained from the operational test program firings/test conducted by SAC in order to increase the sample size, and (3) refine the statistical data analysis procedures so that more information is obtained from the existing data. The techniques developed for the SRAM surveillance program could be used in surveillance programs for new missile system or could be used to improve existing surveillance programs.

This document summarizes the steps in the SRAM surveillance program as follows:

A. Program Requirements/Planning/Scheduling

B. Age sensitive item assessment and failure mode evaluation methods.

C. Hardware selection criteria (components from surveillance program field hardware for test, special test components, and support/test equipment).

D. Hardware test requirements/Test Data Analysis

E. Hardware evaluation criteria

F. Data requirements/Data Storage and Retrieval Procedures

G. Regression analysis criteria and procedures

H. Service life estimate procedures

I. Service life estimate (FY 74)

Figure 1-1 illustrates how these steps relate to the SRAM service life estimate. The more detailed procedures and the service life estimate are reported in the separate documentation listed in the Reference List.

1.2 SRAM MISSILE SYSTEM/MOTOR DESCRIPTION

1.2.1 SRAM System

The WS-140A Weapon System features the AGM-69A SRAM missile (Figure 1-2) launched from a B-52 or FB-111 and eventually a B-1 aircraft. The SRAM missile is a strategic weapon armed with a nuclear warhead. The missile range, speed and accuracy allow the carrier aircraft to "stand off" from its intended targets and launch missiles outside enemy defenses. Through the use of a two pulse motor, missile flight can be programmed for Trajectory options (Figure 1-3). Missile velocity can be optimized for maximum penetration velocity or for maximum average velocity throughout its flight. Trajectory options allow semiballistic flight to the target (high level), or low level with or without the use of the on-board radar altimeter.

1.2.2 SRAM Motor

The SRAM solid rocket motor depicted in Figure 1-4 provides the necessary thrust and impulse to the missile to meet range and velocity requirements and to arm the warhead. It is 100 inches long, 17.6 inches in diameter and contains two end burning solid propellant grains with a total propellant weight of 1000 pounds. A composite propellant is used with a burn rate of 2.3 inches/second.

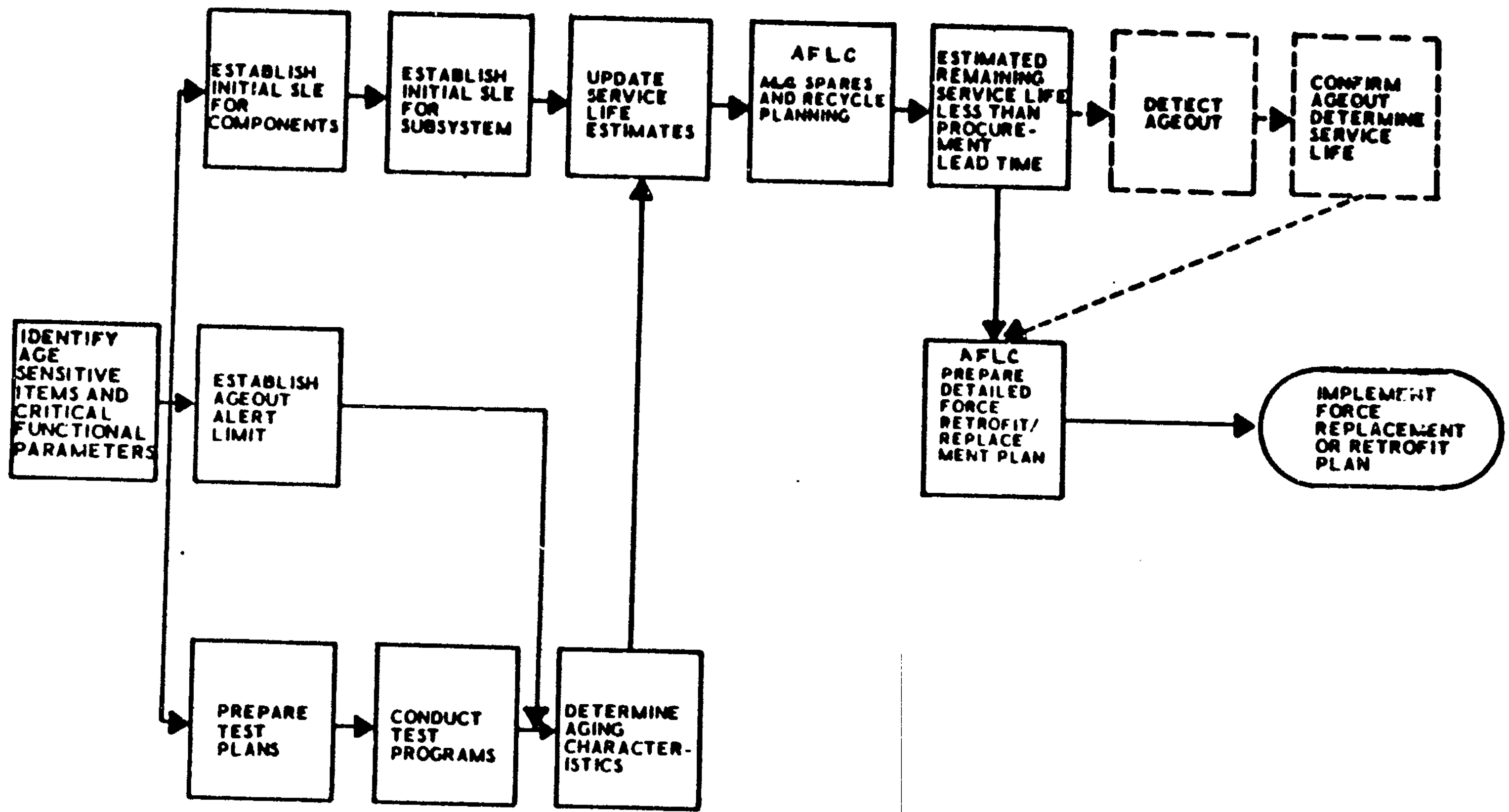
1.2.3 SRAM Components

The SRAM explosive Components are of two types - Electro Explosive Devices (EED's) and thermally fired explosive devices. The EED's are hot wire initiated, where a resistance wire is electrically heated to the ignition temperature of the adjacent pyrotechnic material. The thermally fired unit consists of a small amount of explosive propellant contained in a piston cylinder arrangement. When heat resulting from a fire hazard situation raises the temperature of the device, and subsequently the propellant to ignition temperature, the device will function.

1.2.4 Surveillance Selected Components

The SRAM system components selected for surveillance are listed below. Schematics of the components, general locations and arrangement are shown on Figure 1-5.

AGM-69A SRAM SYSTEM SURVEILLANCE PROGRAM FLOW CHART



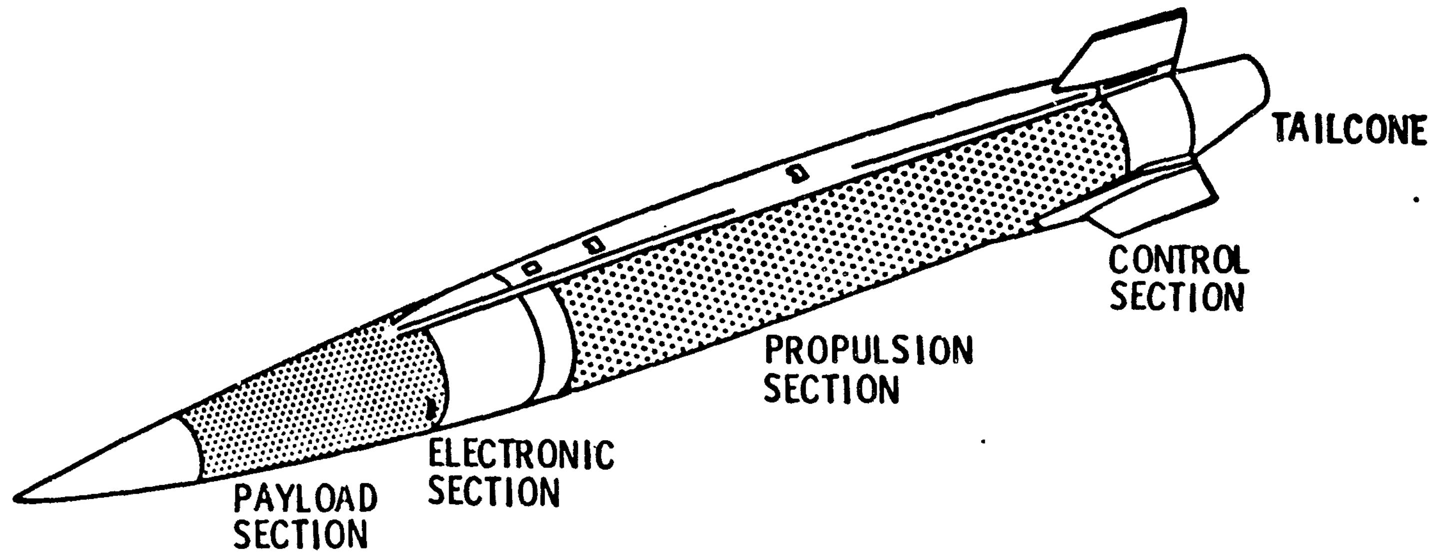


FIGURE 1-2
SHORT RANGE ATTACK MISSILE (SRAM)

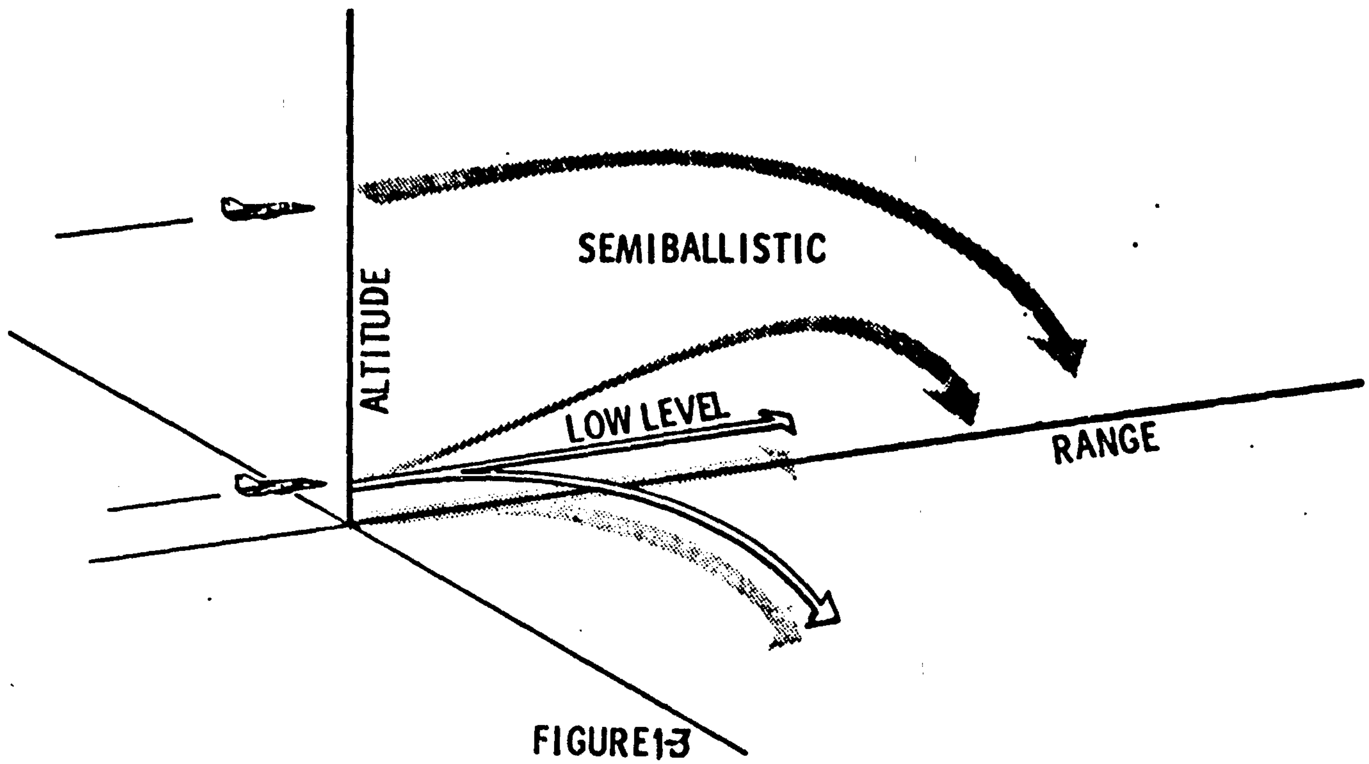


FIGURE 1-3
SRAM PERFORMANCE OPTIONS

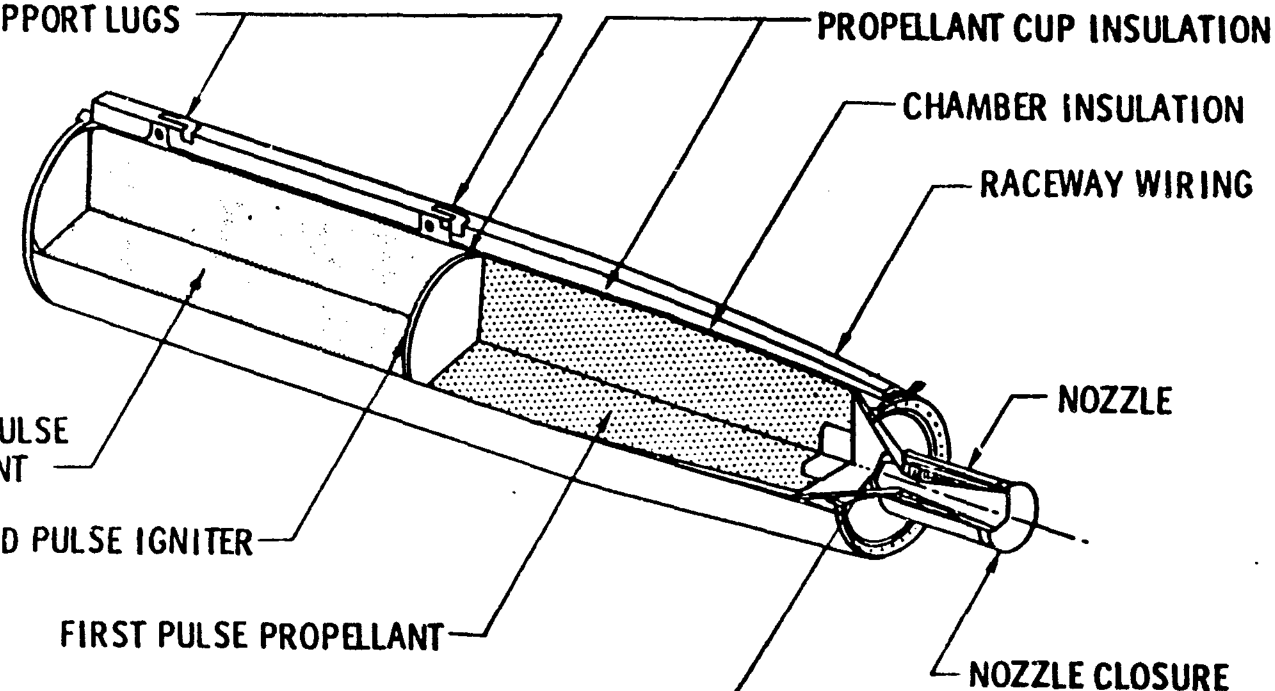
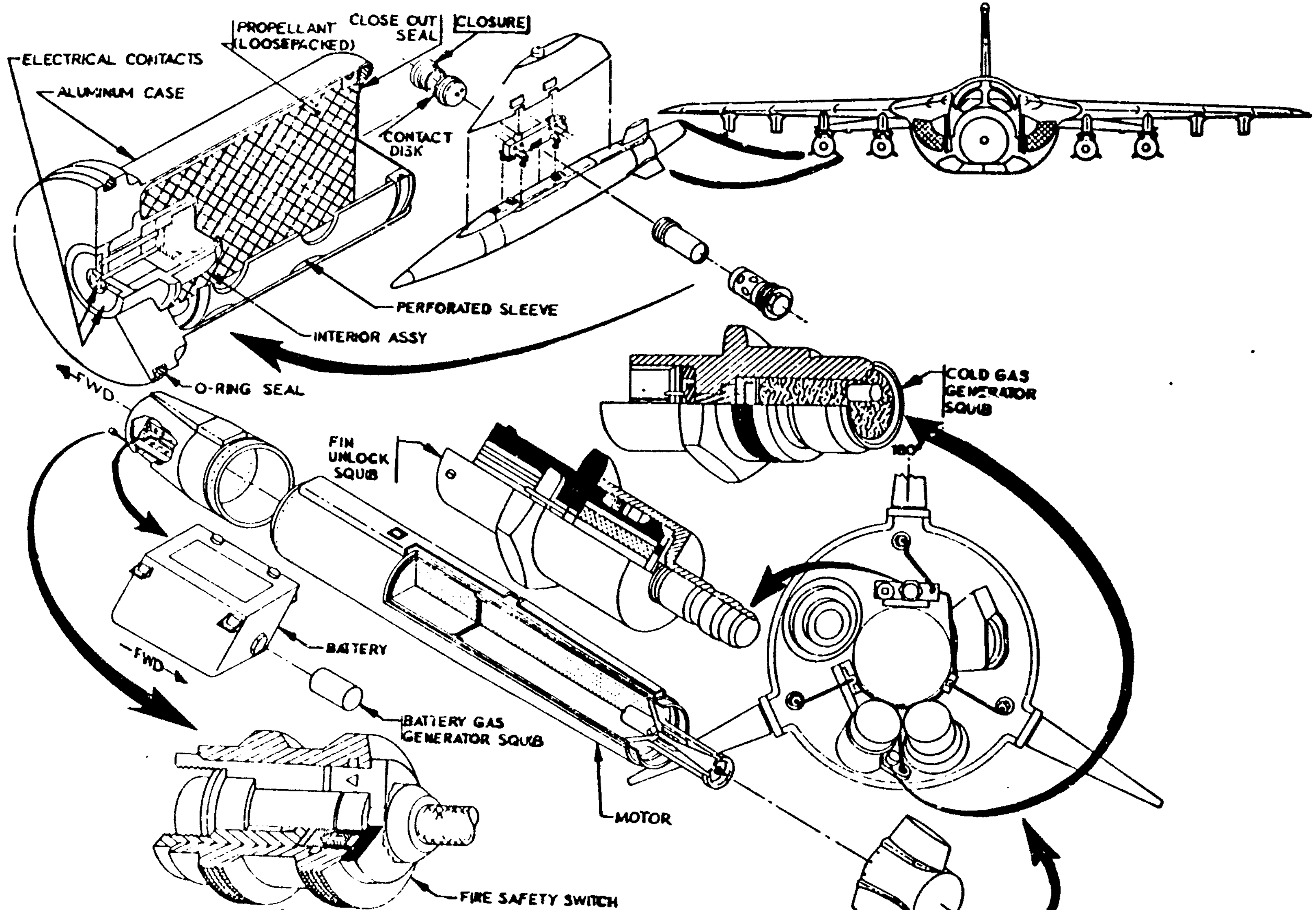


FIGURE 1-4 PROPULSION CONFIGURATION



CARRIER AIRCRAFT/AIR VEHICLE ORDNANCE & ROCKET MOTOR

FIGURE 1-5

SRAM Booster Components

Propulsion Subsystem	P/N 25A43849-101-13 (20A14004) Boeing Aerospace Co. (See also Fig. 1-4)
Battery Power Supply *	P/N CAP4367-11-3 (20A11501) Eagle Picher
Battery Power Supply *	P/N P5560-10-1 (20A14011) Yardney Electric
Battery Gas Generator Squib	P/N 31-00-013-2 (GG201-3) (20A11501) Eagle Picher (Eagle Picher Battery)
Battery Gas Generator Squib	P/N GG220 (20A14011) Eagle Picher (Yardney Battery)
Electrical Cable Assy.	P/N 50-2200-111-19 (20A11411) Unidynamics/Phoenix
Igniter Pressure Cartridge Assy. (cold gas generator Squib)	P/N 280440 - Walter Kidde & Co. P/N 9393-1 - Holex
Fin Unlock System Pressurization Squib	P/N 7882-2 (20A11502) Holex

SRAM Ejector (FB-111 Aircraft)

Missile Ejection Cartridge	P/N 2151800-0 (CCU-16/B 20A14438A) OEA

Operational Test Launch (OTL) Components **

Detonator, Command Destruct Subsystem	P/N 1471-03 (27A10640) Quantic Industries
Explosive Transfer Assy., Command Destruct Subsystem	P/N E24616 (27A10606) Thiokol Chemical Corp.
Linear Shaped Charge, Command Destruct Subsystem	P/N E24817-01 & 02 (27A10641) Thiokol Chemical Corporation

* Items identified by an asterisk may be covered in part in the "Service STAR" testing under AFR 400-46 and AFLC PDI-69 to meet the additional requirement of AFR 136-6 Reference 2.

** Destruct Ordnance is included in the Surveillance Program to the extent specified in paragraph 2.1.7.

1.3 PROGRAM OVERVIEW

The primary surveillance program objective is to predict the shelf and service life of the SRAM rocket motor and explosive components (illustrated in Figure 1-5) to provide orderly replacement of components, thus maintaining a fully effective weapon system. The advantages in weapon system force maintenance is shown on Figure 1-6. The approach to achieve this objective consists of the following:

- To periodically test, evaluate and analyze the physical and functional characteristics of the rocket motor and designated explosive components.

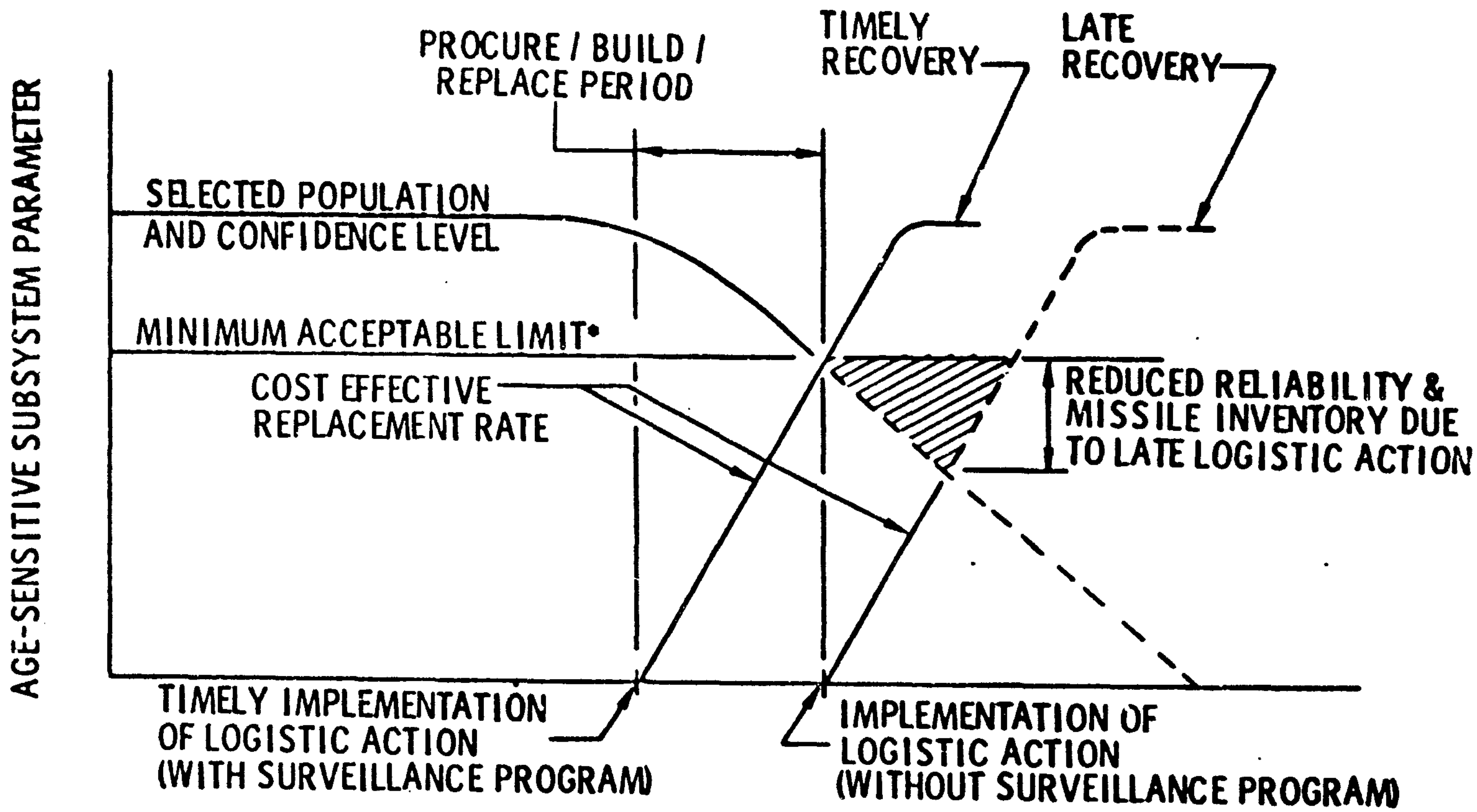
- To determine any change or degradation with time and/or environmental exposure of the rocket motor and each explosive component on the basis of periodic testing and/or hardware evaluation.

- To establish evaluation limits of the rocket motor and each explosive component.

- To project, on a timely basis, when the hardware will degrade below the established limit or required reliability.

Because of the large amount of data required to support the surveillance program, a modularized data bank and computer program (see Figure 1-7) has been established and designed with the capability to maintain data on each production part delivered to the field, assist in the selection of components to be tested in the program, and to identify and recall components that are "over-age." Utility programs are used to sort, transfer and print the data for test hardware selection; data analysis; normalization of parameters; regression analysis; and service life presentations. This data system capability also provides SAC the ability to utilize the "lead the fleet" concept to limit or program missile/fleet effectiveness and reliability to the critical aging effects, i.e., number of flight hours, etc.

A service life estimate is planned annually. The two dimensional format for presenting the selected parameter/component estimate is shown on Figure 1-8. A family of plots is provided for each of the parameters being evaluated as a function of the various aging measures for each component.

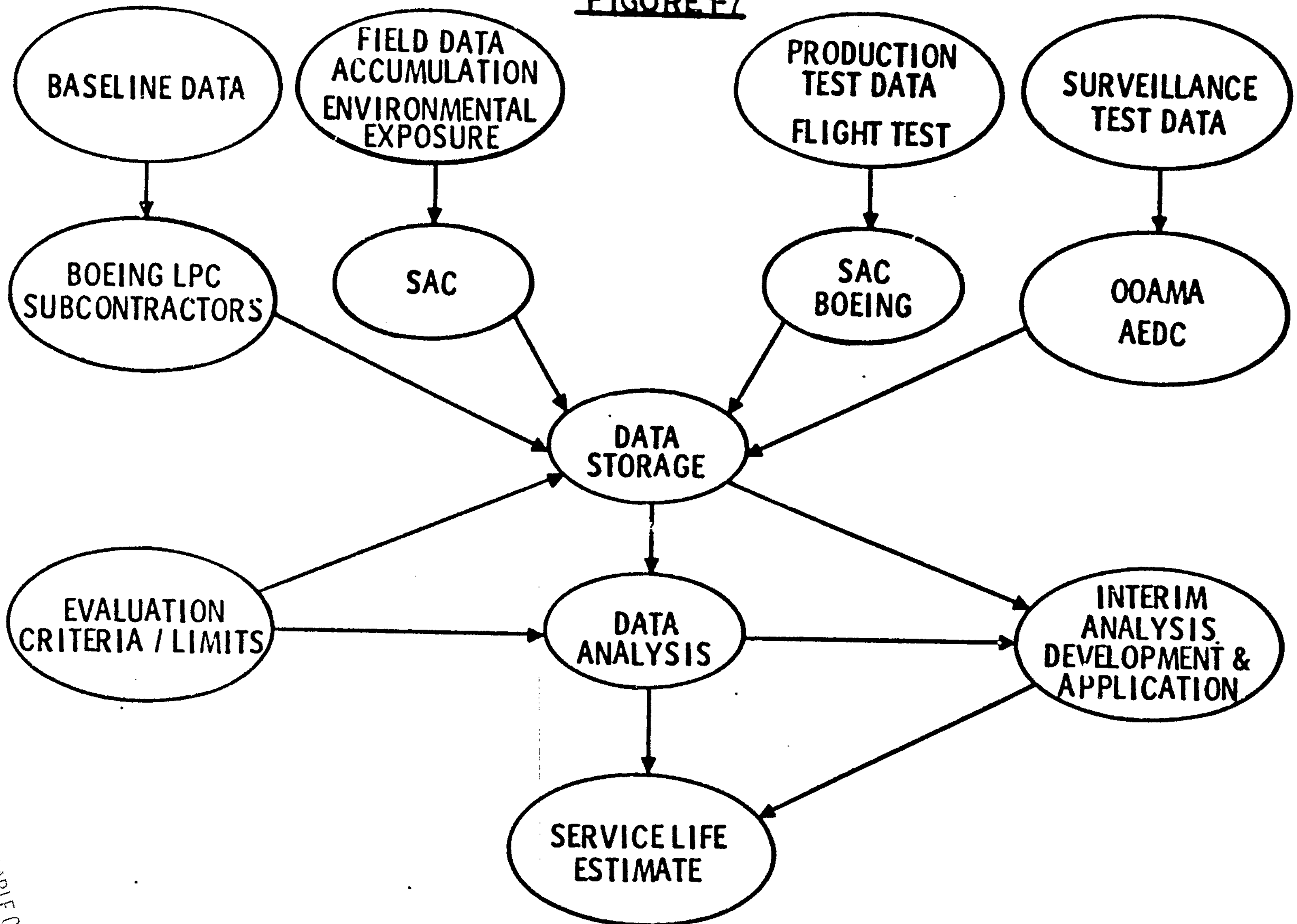


EXPOSURE / AGE TIME →

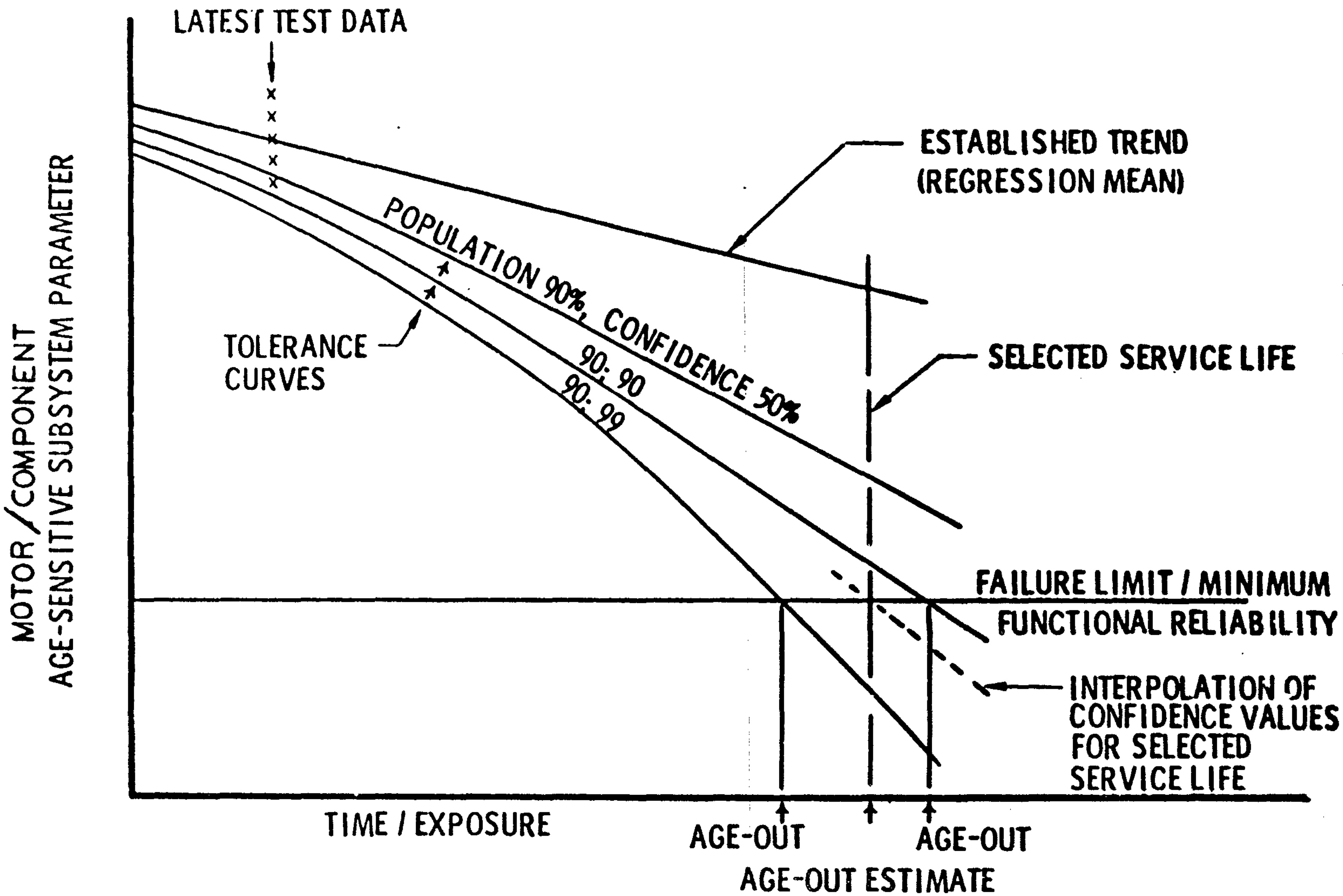
*SAME PHILOSOPHY APPLIES TO MAXIMUM ACCEPTABLE LIMITS

FIGURE 1-6 PURPOSE OF SURVEILLANCE PROGRAM

DATA RELATIONSHIP
FIGURE 1-7



SRAM SERVICE LIFE ESTIMATE TECHNIQUE
FIGURE 1-8



1.4 SRAM SURVEILLANCE PROGRAM WORKING GROUP (SSPWG)[1]

The Explosive Component Surveillance Program is dependent upon many agencies and people. The yearly Service Life Estimate is made by a joint AFSC, AFLC, AFRPL and Contractor team comprised to form the SRAM Surveillance Program Working Group. This Group was established to assist the program manager, assign specific tasks, resolve problem areas, provide technical guidance, and evaluate data and resulting conclusions. The prime agencies are as follows:

- Aeronautical Systems Division (ASD) - Program Technical/Policy Manager
- Ogden Air Logistics Center (ALC), Hill AFB - Testing, evaluation and analysis manager
- Oklahoma City Air Logistics Center (ALC) - Logistics SRAM System Manager
- Air Force Rocket Propulsion Laboratory (AFRPL) - AF Rocket Motor Technical Experts
- Strategic Air Command (SAC) - SRAM User
- Contractors (Boeing - SRAM Prime Contractor and System Technical Consultant/Lockhead - SRAM Motor Manufacture and Technical Consultant)

1.5 SURVEILLANCE SCHEDULES

The overall explosive component surveillance program and schedule is presented on Figure 1-9. A typical yearly testing schedule for the rocket motor and small ordnance is presented in Table 1-1. These detail schedules are also contained in Boeing Document D220-10096-1, "SRAM Weapon System Program Schedules - Production" as shown below. These schedules are updated and submitted to the Air Force as a CDRL item on a monthly basis.

P1.16 sheet A, Explosive Surveillance Program - Small Ordnance
P1.16 sheet B, Explosive Surveillance Program - Rocket Motor
P1.16 sheet C, SRAM Explosive Component Surveillance Program

1. Reference (4) established the Charter for the Working Group 10.

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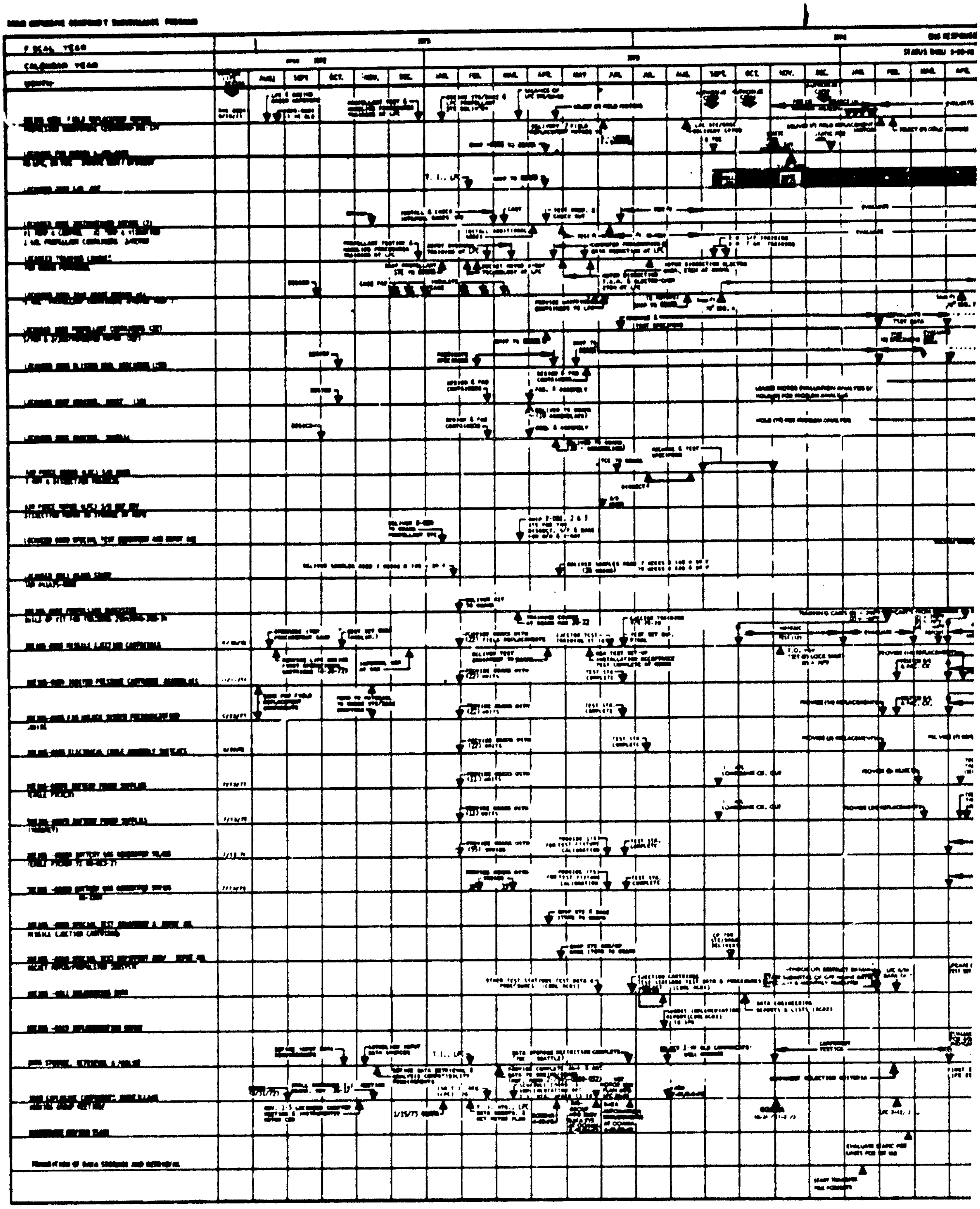

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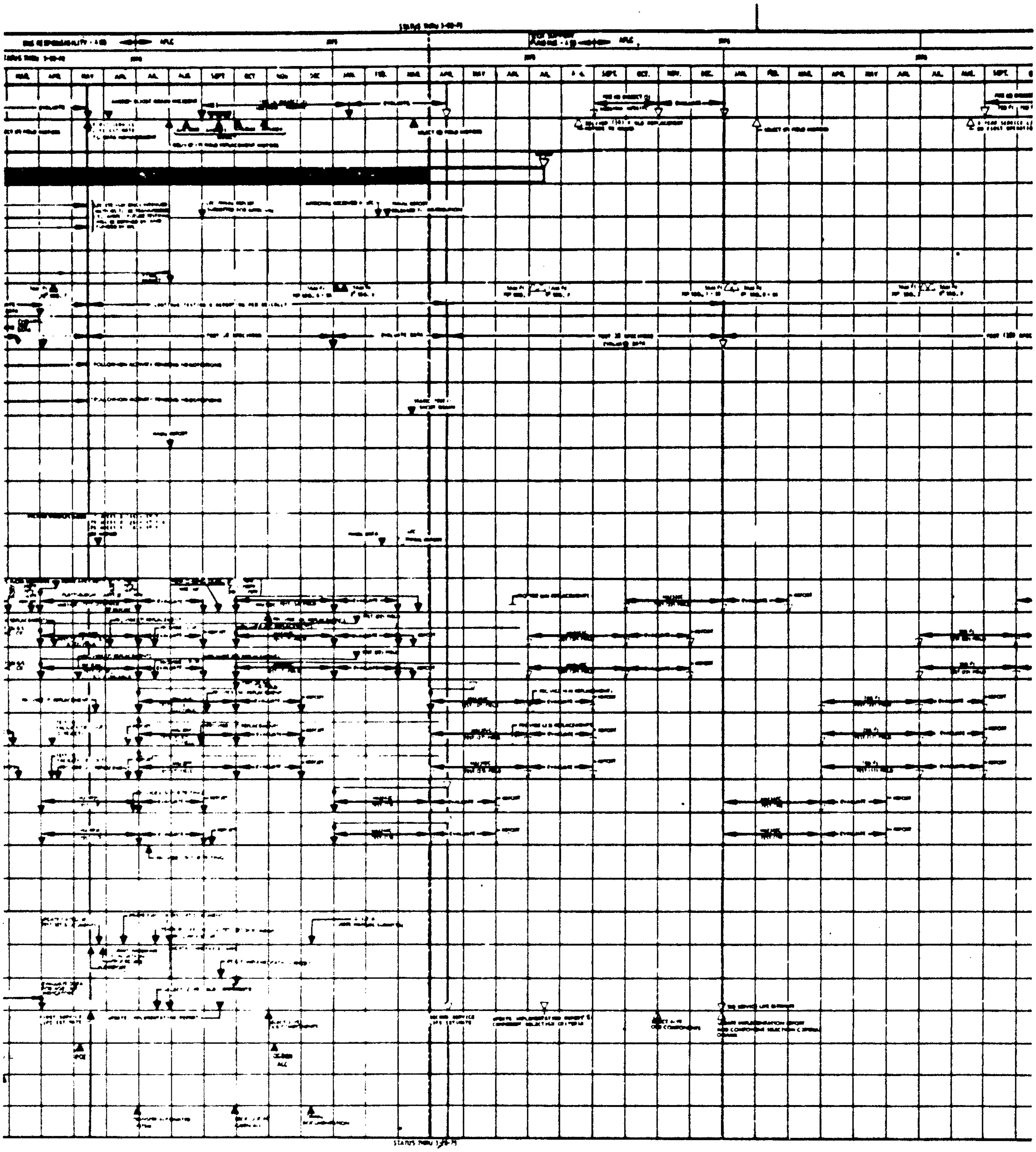

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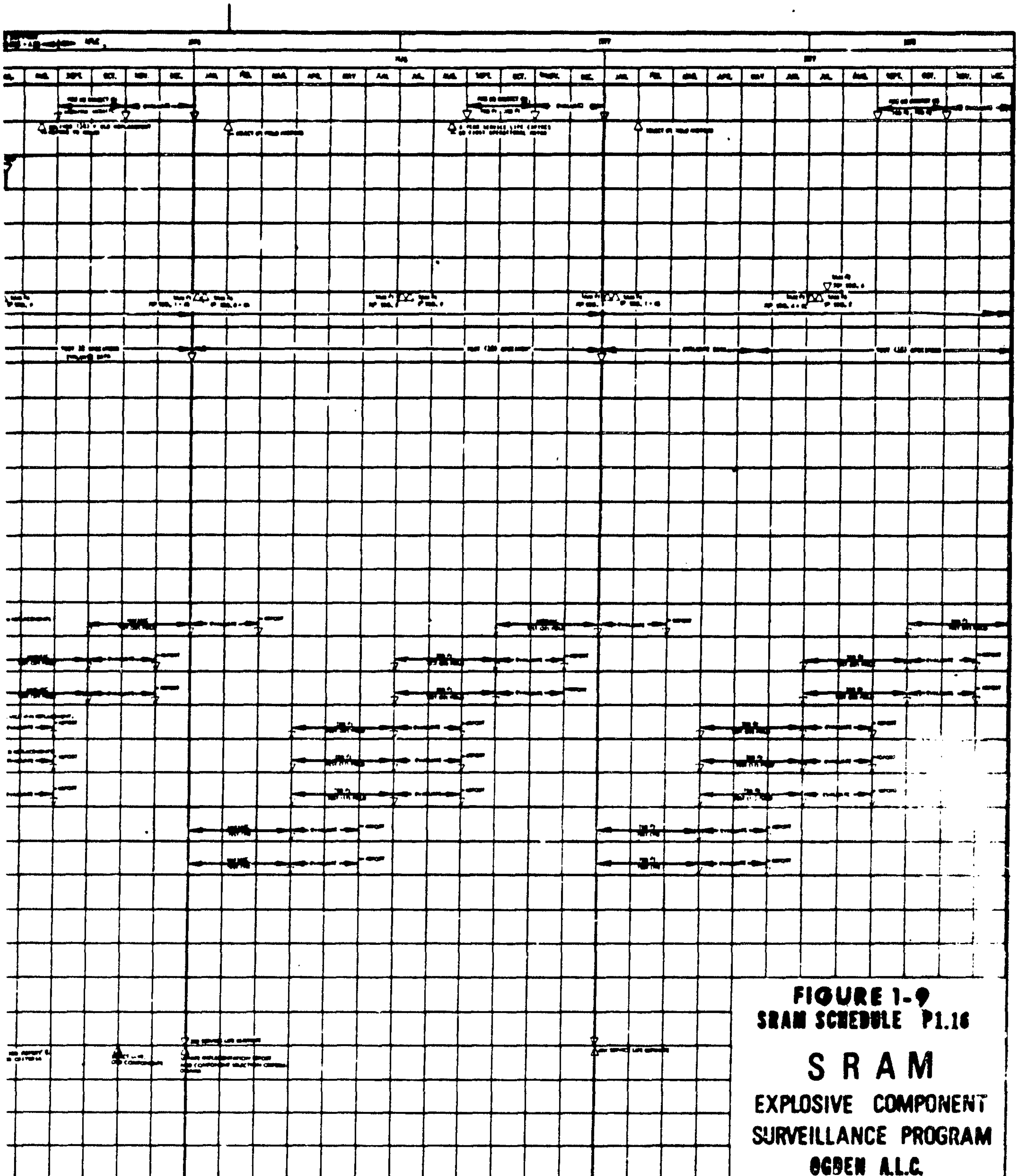

FIGURE 1-9
SRAM SCHEDULE P1.16

SRAM
EXPLOSIVE COMPONENT SURVEILLANCE PROGRAM
OGDEN A.L.C.

TABLE 1-1

TYPICAL SURVEILLANCE PROGRAM
YEARLY SCHEDULE

	QUANTITY TESTED/YR
LABORATORY PROGRAM (MATERIAL SAMPLES)	
FIELD MOTOR DISSECTIONS	2
TAKE APART MOTOR SAMPLES	2
PROPELLANT SAMPLES	18
BOOST/SUSTAIN IGNITERS	2
COMPONENT PROGRAM	
FIN UNLOCK SQUIB	22
IGNITER PRESSURE CARTRIDGE	22
BATTERIES (2 SOURCES)	22
BATTERY GAS GENERATORS (2 SOURCES)	22
ELECTRICAL CABLE SWITCH ASSY.	22
MISSILE EJECTOR CARTRIDGE	22
FIELD MOTOR FIRINGS	5

SECTION II

Service Life Estimate Procedure

2.0 GENERAL

Procedures for estimating the service life of a hardware item have been developed and are now being used by OOAMA to support Minuteman and other surveillance programs. The SRAM service life estimate technical approach and general procedure are basically the same as developed for the Minuteman Program, (References 16 thru 22). The detailed steps for SRAM surveillance in terms of major subjects were shown in Figure 1-1.

The initial step for the SRAM surveillance program, as for Minuteman, was to evaluate all items within each explosive component to determine those items which are susceptible to aging and which could have a detrimental impact upon the component and the SRAM Weapon System. The identification, assessment, postulated aging mechanism, failure mode evaluation and identification of data sources provide:

(1) Substantiation for an initial service life estimate which should equal the design life of the components as a minimum.

(2) A complete critical items assessment.

(3) The basis for the surveillance program test objectives, specific tests and test requirements.

(4) Selection criteria for components to be tested in the Surveillance Program.

Hardware items are then withdrawn from Air Force operational use for surveillance testing that have experienced typical environmental conditions as well as those believed to be severe and/or damaging to the components. The selection criteria developed from the age-sensitive item assessments above are then combined with the specification system analysis and evaluation requirement values and used as the basis for field item selection and testing. The hardware samples selected should represent the effects of both average and severe usage conditions to provide trend data for the units in field service. The SRAM program, unlike Minuteman, has the capability to monitor the operational exposure and depict those effects that are the most severe.

The data gathering, storage and retrieval program was generated to provide component usage tracking capability and visibility for hardward selection, data analysis, normalization of parameters, regression analysis, and service life estimates/presentations.

The remaining data input is the failure criteria that supports a service life estimate. Included also are the visual examination requirements for the review of hardware condition, and acceptance criteria which are found to be significant in the development of SRAM.

The data obtained from the various surveillance tests are treated by regression analyses to determine degradation from zero-time performance data as a function of age, flight hours, installation cycles, etc. Only those key performance parameters which significantly affect the success or failure of the missile system, are regressed. The actual Service Life Estimate is determined for the time when the key parameter regresses to its failure limit.

The service life estimate is run when sufficient surveillance data becomes available to conduct statistical regression analyses and an engineering evaluation of hardware.

The general procedure for establishing and evaluating the service life of SRAM components consists of statistically projecting each age sensitive parameter mean value and tolerance curves for selected population and confidence values to where the selected tolerance curve intersects a failure line as shown in Figure 1-8. This intersection indicates age-out and establishes the time (or limit of other aging measures) from which to predict the beginning of procurement of replacement components. An alternate technique for interpreting regression analysis results is to first specify a service life (e.g., 5 years) and a reliability (e.g., 90%) then determine the confidence level of the tolerance curve that intersects the failure limit at the specified service life as shown in Figure 1-8. This is done for all parameters to determine the one with the smallest confidence value. This is the confidence value assigned to that component.

The physical condition of aged motor hardware is determined by an engineering inspection. Observed results are evaluated for potential age-out effects on component integrity. When sufficient data are accumulated, age sensitive parameters determined from inspection will become amenable for statistical regression analyses.

The specific procedures applicable to each explosive component are discussed in detail in Appendix B and C and summarized below.

2.1 Age-Sensitive Item Identification and Assessment

Reference 5 presents the procedures for identifying and assessing the age-sensitive items of each component with definition of the failure criteria for these items. The age-sensitive item identification is accomplished by the following steps:

A. Age-sensitive items of the components and their subassemblies parts, materials, and material interfaces are Identified and provided an age-sensitive rating. These ratings are used to assist in preparing an

initial service life estimate and in establishing a surveillance test program that investigates the critical aspects of the components being evaluated.

B. For each item identified in paragraph 2.1.A above, the postulated aging mechanisms, failure modes associated with these mechanisms and critical material properties are listed.

C. Then, the specific parameter to be tested, and its relationship to the property or function critical to operation of the component are listed. The failure limit for the parameter tested, or the method by which that limit is to be determined is then defined.

D. For items rated sensitive to age-out (see Table 2-1), testing on the material, subcomponent, component, and subassembly levels is considered advisable, while testing only on the full scale propulsion system level may be adequate for items rated moderately sensitive or insensitive.

E. The product of the Age-Out Sensitivity (AOS) and the margin of safety rating yields the critical item rating.

2.2 Test Requirements for Age-Sensitive Items

In formulation of a test program to provide the necessary Surveillance Program data, the critical item assessment discussed in paragraph 2.1 is considered as well as available analytical conclusions relating to aging effects. The SRAM test program was defined considering the critical item assessments discussed and are contained in the test requirement documents listed in Table 2-1. The overall test approach for the SRAM explosive components presented herein was originated by the SSPWG. Continuous evaluation and reassessment of this program will continue throughout its life.

A. Rocket Motor Test Requirements

Tests to obtain data for the service life estimate, including definition of procedures, instrumentation and data requirements are included in this section. (See Table 2-1). Ballistic tests and associated regression parameters are identified in Table 2-2. Mechanical Property tests and associated structural regression parameters are identified in Table 2-3.

1. Tests for Ballistic Data

Ballistic data is obtained from three sources: operational rocket motors static firings, Operation Test and Evaluation (OT&E)/ Operational Test Launch (OTL) flights and Group Acceptance Test (GAT) firings.

TABLE 2-1
Component Identification, Assessment and Test Requirements

		COMPONENT	AGE-SENSITIVE ITEM ASSESSMENT	TEST REQUIREMENTS: SURVEILLANCE TEST SET	TEST REQUIREMENTS: ATP/LAT/QTP
		MISSILE EJECTION CARTRIDGE	Initiation Charge Ignition Charge Booster Charge Output Charge Encasement Materials Header Assembly Bridgewire Circuit Electrical Connection Insulation/Seals	21A14172 20A11537 0220-10241	2151-85/D 2151-79 20A14438 2151800
MISSILE COMPONENTS	FLIGHT CONTROL ACTUATOR ASSEMBLY	IGNITER PRESSURE CARTRIDGE	Initiation Charge Ignition Charge Output Charge Encasement Materials Header Assembly Bridgewires and Circuits Electrical Connection Insulation/Seals Component Interfaces	21A14260	TP-1129 20A11513 9393-1
MISSILE COMPONENTS	FLIGHT CONTROL ACTUATOR ASSEMBLY	FIN UNLOCK PRESSURIZATION SQUIB	Initiation Charge Ignition Charge Sustainer Charge Output Charge Encasement Materials Header Assembly Bridgewire and Circuits Electrical Connection Insulation/Seals Component Interface	21A14254	TP-1072 20A11502 280440 7888-2
MISSILE COMPONENTS	ELECTRONICS/GUIDANCE SECTION	ELECTRICAL CABLE ASSEMBLY SWITCH	Explosive Charge Encasement Materials Environmental Seals Electrical Connections Component Interfaces	21A14257	50-2000-ATP-20 20A11411
MISSILE COMPONENTS	ELECTRONICS/GUIDANCE SECTION	BATTERY POWER SUPPLIES	Electrical Connectors & Terminals Battery Activation System Cell Assemblies EMI Filter Assembly Heater/& Thermostats Intercell Connectors Relief Valves	21A14256	Yardney ATP-315 Eagle Picher LATP-270 ATP-271
MISSILE COMPONENTS	ELECTRONICS/GUIDANCE SECTION	BATTERY GAS GENERATORS	Ignitor Squibs (2) Ignition Materials Header Assembly Bridgewire Encasement Materials Gas Generator Propellants Glass to metal seals & seals Solder Connections Encasement Materials	21A14255	GG-220 LATP-297 GG-201-3 ATP-190 QTP-116
MISSILE COMPONENTS	PROPULSION SUBSYSTEMS	ROCKET MOTOR	Propellant Internal Insulation Boost Initiator & Igniter Sustain Initiator & Igniter Nozzle/Nozzle Closure Chamber and Interfaces Missile Lug and Clevises External Insulation Raceway Headcap/Seals	21A14401 2K-SR75-3 21A14403 21M-AGM69A-26 21A14404 21A14405 21A14406 21M-AGM69A-3	EC20A14004 TRS1025 ETR1025 LPC579-P-51

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TABLE 2-2

SRAM MOTOR - REGRESSION BALLISTIC PARAMETERS

ORIGINAL PARAMETER	REVISED PARAMETER	SYMBOL	REASON
1st PULSE	1st Pulse		
• CHAMBER PRESSURE, MAXIMUM	• Chamber Pressure, Maximum	$P_{MAX\ 1}$	• Case Burst
• THRUST, AVERAGE	• Thrust, Average	$F_{AVG\ 1}$ or AVG F1	• Warhead Arming
• IGNITION TIME	• Start Time	T_{START}	• Ground Impact & Propellant Retention
• THRUST DECAY TIME	• End Time	T_{END}	• 2nd Pulse Ignition
• IMPULSE, % TOTAL	• Impulse	I_{T1}	• Warhead Arming 2nd PULSE IGNITION
2nd PULSE	2nd Pulse		
• CHAMBER PRESSURE, MAXIMUM	• Chamber Pressure, Maximum	$P_{MAX\ 2}$	• Case Burst
• THRUST, AVERAGE	• Thrust, Average	$F_{AVG\ 2}$ or AVG F2	• Penetration Velocity
• IGNITION TIME	• Start Time	T_{START}	• Flight Control
MOTOR	Motor		
• IMPULSE	• Impulse	I_{TM}	• Range

Ballistic Parameter Definitions

F_{AVG}	Average thrust, average sea level thrust over action time (lbs.)
I_T	Impulse, integral of sea level thrust over action time (lb-sec)
P_{MAX}	Maximum pressure, maximum instantaneous chamber pressure (psia)
T_{ACT}	Action time, time interval from 10% of maximum pressure following grain ignition to 10% of maximum pressure preceding motor extinguishment (sec)
T_{END}	End time, time interval from ignition signal to end of action time (sec)
T_{DECAY}	Thrust decay time, time interval from end of burn time (Reference 5, Section 12.0) to end of action time (sec)
T_{IGN}	Ignition time, time interval from ignition signal to 75% of the pressure at 2 seconds (sec)
T_{START}	Start time, time interval from ignition signal to 1100 psi (sec)

BALLISTIC TEST DATA

- Age zero cured strand burn rate from acceptance tests of each production propellant batch
- Age zero motor performance from motors fired for production motor group acceptance tests (GATs)
- Motor data from missile operational test and evaluation (OT&E) flights
- Ogden Air Logistics Center surveillance motor firings
- Ogden Air Logistics Center surveillance dissect motor

TABLE 2-3

SRAM MOTOR - REGRESSION STRUCTURAL PARAMETERS

ORIGINAL PARAMETER	REVISED PARAMETER	REASON
• PROPELLANT STRESS, 70°F • PROPELLANT STRESS, -65°F • PROPELLANT STRAIN, 70°F • PROPELLANT STRAIN, -65°F • PROPELLANT MODULUS, 70°F • MARGIN OF SAFETY	• TEST RATIOS • PROPELLANT STRESS • PROPELLANT STRAIN • PROPELLANT MODULUS • MARGIN OF SAFETY	• STRUCTURAL INTEGRITY

SUMMARY OF MECHANICAL PROPERTIES EVALUATION OF MOTORS

MATERIAL TEST	PARAMETER MEASURED	PURPOSE OF TEST
JANNAF UNIAXIAL TENSILE	σ (psi) ϵ (%) E (psi) STRESS, STRAIN, MODULUS TRUE STRESS/SECANT MODULUS RATIO	HISTORICAL PROPERTIES QUALITY COMPARISON
BIAXIAL TENSILE (STRIP)	MAX MAX STRESS, STRAIN, UNIAXIAL TO BIAXIAL RATIO	PROVIDE STRESS, STRAIN ALLOWABLES FOR STORAGE ANALYSIS AFTER AGING
BIAXIAL (WITH SLIT) TENSILE	TEAR FRACTURE COHESIVE ENERGY	CRACK PROPAGATION DETERMINATION
MINI-THIN TENSILE	STRESS, STRAIN, MODULUS	EVALUATE MATERIAL DEGRADATION IN THE PROPELLANT/INSULATION INTERFACE AREA
SHORE "A"	HARDNESS	DETERMINE PROPELLANT HARDNESS
STRESS RELAXATION	MODULUS (E_R)	DEGRADATION IN STORAGE AND FIRING ALLOWABLE
BONDED PLATE BLISTER PEEL	ADHESIVE FRACTURE	MEASURE ADHESION IN PROPELLANT/ LINER/INSULATION BONDS
DIAMETRAL COMPRESSION	STRESS, STRAIN TENSION-COMPRESSION	MULTI-AXIAL PROPERTIES FOR DETERMINING FIRING ALLOWABLES
BOND-IN-TENSION	BOND TENSION	DETERMINE INSULATION/PROPELLANT INTERFACIAL STRENGTH
BURN RATE	BURNING RATE/PRESSURE EXPONENT IN/SEC @ T&P	BALLISTIC PROPERTIES OF DISSECTED MOTORS
PEEL	PEEL STRENGTH (PLI)	COMPARATIVE INSULATION/PROPELLANT INTERFACING STRENGTH
MOISTURE CONTENT	WEIGHT PERCENT WATER	MOISTURE IN LINER/INSULATION IN BOND PAD AND RELEASED AREAS
ALKYL FERROCENE CONTENT	WEIGHT PERCENT AKF	MIGRATION IN PROPELLANT/LINER/ INSULATION
THERMAL COEFFICIENT OF LINEAR EXPANSION	EXPANSION GRADIENT	STORAGE ALLOWABLE DETERMINATION
BULK MODULUS *		COMPRESSIBILITY OF MATERIAL
SOL GEL *	% SOL GEL/% WELL RATIO	DETERMINE GEL FRACTION AND SWELL RATIO

* MEASUREMENTS WERE DROPPED FROM PROGRAM BUT MAY BE REINSTATED AT A LATER DATE IF REQUIRED

STRUCTURAL TEST DATA

- OGDEN AIR LOGISTICS CENTER SURVEILLANCE DISSECT MOTOR
- AGE ZERO LOCKHEED DISSECT AND TAKE APART MOTOR DATA
- AGE ZERO JANNAF SPECIMEN DATA FROM ACCEPTANCE TESTS OF EACH PRODUCTION PROPELLANT BATCH

2. Tests for Physical Properties

Dissection of SRAM rocket motors returned from the field and of Take-apart motors (TAM) were included in the Surveillance Program to determine changes in propellant physical properties associated with field usage. The dissection includes electrochemical cutting of the steel motor case from field motors or disassembly of TAMs, inspection of the internal condition of the motor and removal of propellant and insulation for laboratory testing.

Data from the dissection of the motors are then used to evaluate the current condition of the motors and to predict the effects of service on the life of motors in the fleet. This is done both by qualitative evaluation of data on the propellant/liner/insulation system and by determination of the structural margin of safety for the motor based on laboratory data. The observed conditions are then extrapolated to predict the structural age out of the remaining motors in the fleet.

Propellant and propellant/liner/insulation physical properties, are determined by conducting a series of tests as defined in Table 2-3 and Figure 2-1 and described in detail in Appendix B and References 5 and 8.

B. Explosive Components Test Requirements

Surveillance testing is performed in the same manner as production acceptance testing for each SRAM component. These include destructive (functional) tests and non-destructive tests performed in accordance with the requirements documents listed in Table 2-1 for the parameters in Table 2-4.

2.3 Hardware Selection Criteria

The criteria for selection of field hardware includes storage time or age as in the Minuteman Program, and also SRAM peculiar environmental exposure, missile and equipment use and configuration. This is necessary because of the weapon system operational use over worldwide natural environments and exposure to induced environmental and loading conditions. The SRAM surveillance program was established with the capability to monitor the explosive component environment and depict those parameters that show aging effects and also provide the capability to utilize SAC's lead-the-fleet concept. Each of the critical exposure conditions must be considered for the selection of the surveillance test hardware.

The requirements for the selection of the field service motors/ components for surveillance testing considered the following measures of "aging."

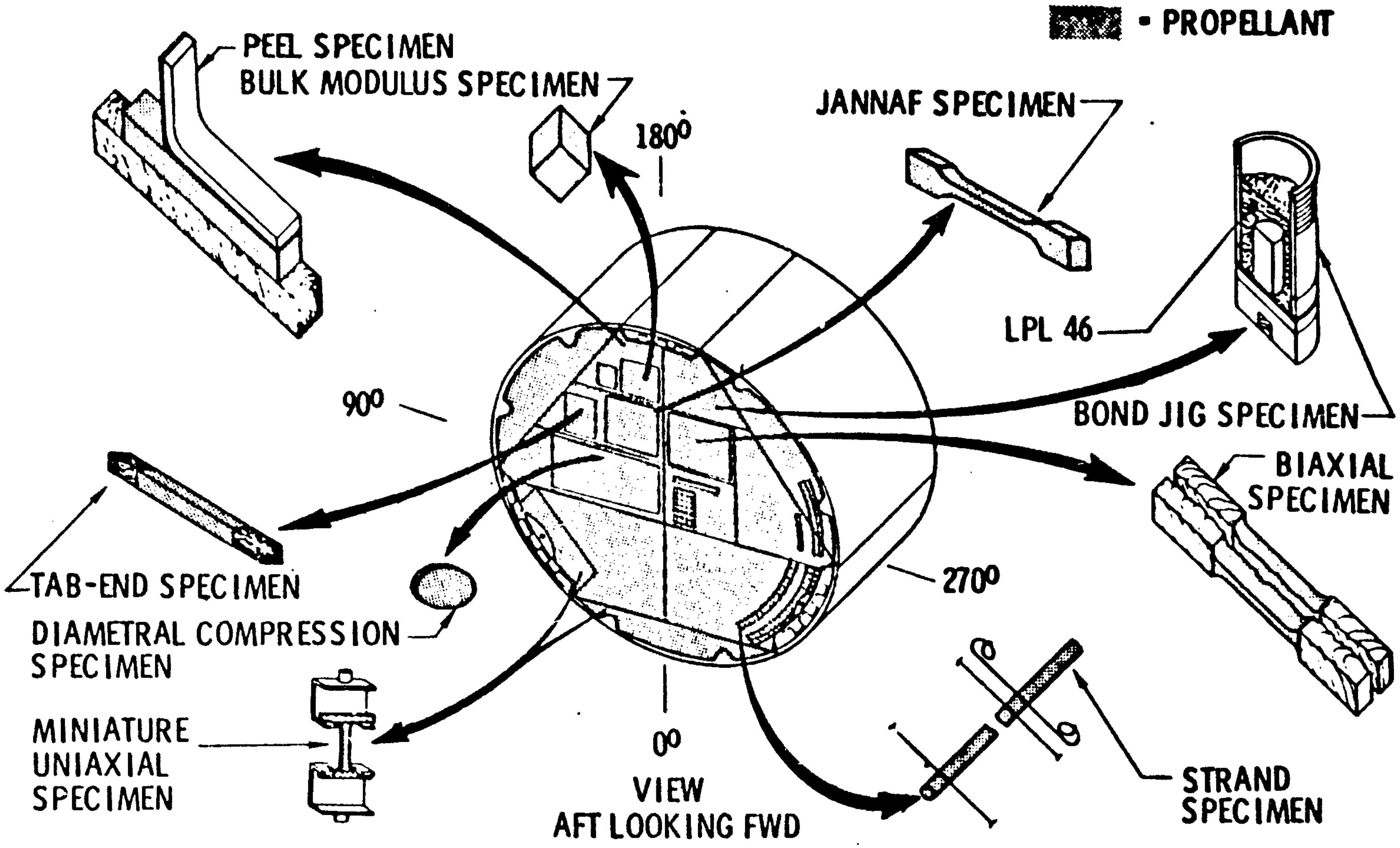


FIGURE 2-1 PROPELLANT PROPERTIES TEST SPECIMENS

TABLE 2-4 SRAM ORDNANCE SURVEILLANCE TEST - ORDNANCES DEVICES - SUMMARY

		TEST PARAMETER																
		CRITICAL												SUPPORTING				ATTRIBUTE
NON-DESTRUCTIVE TEST				●		●			●						●		●	
FUNCTIONAL TEST		●	●		●		●	●		●	●	●	●	●				●
COMPONENT	Applicable Section ▲	Peak Pressure	Ejection Velocity	Bridge Resistance	Time to Pressure & Pressure-Time Curve	Continuity	Operating Time	Voltage-Load-Time	Heater Resistance	Water Displacement	Initiation Time	Battery Drain Time	Time Duration of Applied Current	Operating Time	Insulation Resistance		Unactivated Battery Resistance	Success/Failure
Missile Ejection Cartridge	5.0	●	●	●									●	●	●			●
Igniter Pressure Cartridge Assembly	6.0	●		●	●										●			●
Fin Unlock System Pressurization Squib	7.0			●	●										●			●
Electrical Cable Assembly Switch	8.0					●	●								●			●
Battery Power Supplies	9.0			●				●	●			●					●	●
Battery Gas Generator Squib	9.0	●		●	●					●	●				●			●

▲ The Criteria listed under reference 5 sections 6.0 thru 9.0 are not germane to Section 5.0, but are included in this summary table for easy reference to the Service Life Estimate procedures given. Reference 5 Table 5.6-1.

A. The age, taken from the date of manufacture, must be at least equivalent to the age year in which the service life estimate computation is to be made.

B. Maximum operational service.

In addition to the above, the field service items should be selected from those which are considered to have been exposed to the most severely degrading environments which include, but are not limited to, the following:

C. Maximum flight hours.

D. Maximum number of take-offs and landings experienced when uploaded.

E. Maximum flight hours below 15,000 feet altitude.

F. Temperature extremes which may occur during storage, ground handling, flight line alert and captive flight (sustained high altitude and supersonic dash).

G. High humidity combined with or without temperature cycling during flight line alert or low altitude captive flight.

H. Motors/Components with major anomalies or problems.

The weighting and selection of the first two sampling years motors was accomplished by SSPWG. The members of the working group applied a priority rating to each of the parameters identified above in order of significance to determine a total group rating. Each year a summary of the "most severe" usage motors/components available at the time of selection is provided by computer printout.

For explosive components efforts were made to obtain field selected test components in sample lots of not less than 5, all of which have been exposed to similar environments, possess similar calendar ages, and service life exposure. The test sample (Table 1-1) size of 22 components specified for each year of Service Life Estimate is the minimum size that, when functionally tested with 100% success in an attributes analysis, demonstrates a reliability of 90% with a 90% confidence level for each component which is considered to be the desired acceptable level.

2.4 Data Requirements

A comprehensive computerized data identification, gathering, storage and retrieval program is necessary throughtout the program. The general data storage and retrieval flow overview was illustrated in

Figure 1-7. Automation of this data system was required to provide for each function of a service life estimate. In Figure 2-8, the blocks identified M were in the Minuteman initial program and S were SRAM additive program blocks. The interrelationship and data flow for the SRAM components are presented in Figures 1-7, 2-3 and 2-4. Data identification and specific requirements for the rocket motor and ordnance devices are discussed in Appendices A, B and C, respectively. Three types of data will be used in the surveillance program: Motor/Component-Descriptive Data, Use Data, and Test Data. Careful tracking of the Motor/Component inventory is required to maintain a historical and service life data file to provide the visibility required by the SSPWG for test hardware selection, component usage experience, and data analysis. At the time that significant performance and/or physical property degradations are observed, the total data bank will be available for diagnostic and recommended action type activities.

A. Descriptive Data

The Seven sources identified for motor/component descriptive data are:

1. Group Acceptance Test Directive (Motor only)
2. Manufacturer's acceptance test data (ejector and cartridge)
3. Manufacturer's design and qualification test data
4. Depot repair acceptance test data
5. Ammunition Data Card (DD Form 1650)
6. SRAM Propellant Summary Report (Motor only)
7. Motor Log Book

B. Use Data

Four sources have been identified for motor/component use data:

1. Material Inspection and Receiving Report (DD 250)
2. Requisition and Invoice/Shipping Document (DD Form 119)
3. Maintainability Tape File (AFLC D 056), Reference 23
4. SAC SRAM Data Element Extract Tape (SAC Forms 126 and 126C)

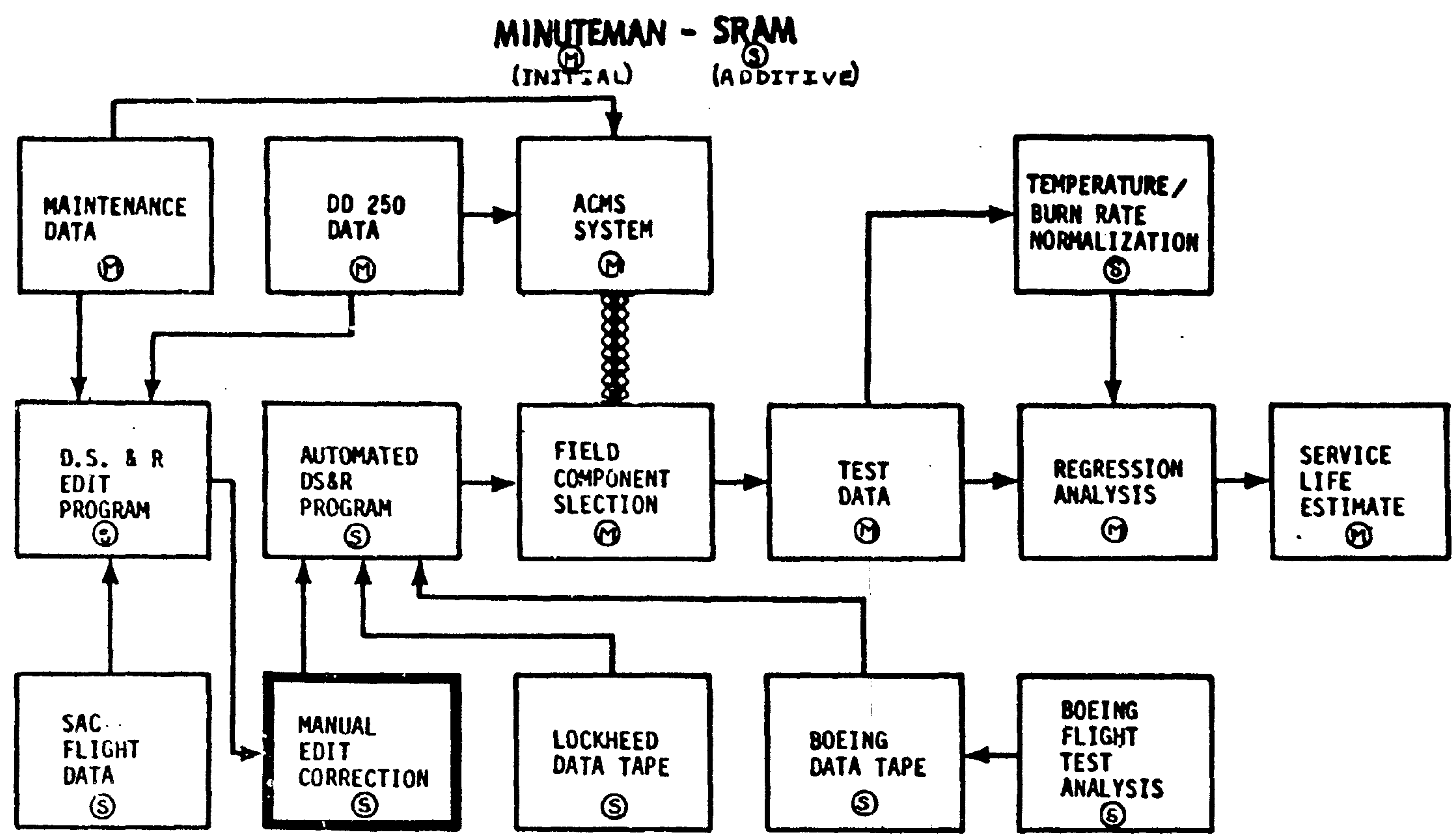
C. Test Data

Five types of test data are available for motor/component age-out predictions:

1. Batch (Statistical) test data
2. Sampling test data

SURVEILLANCE PROGRAM SLE FLOW DIAGRAM

FIGURE 2-3



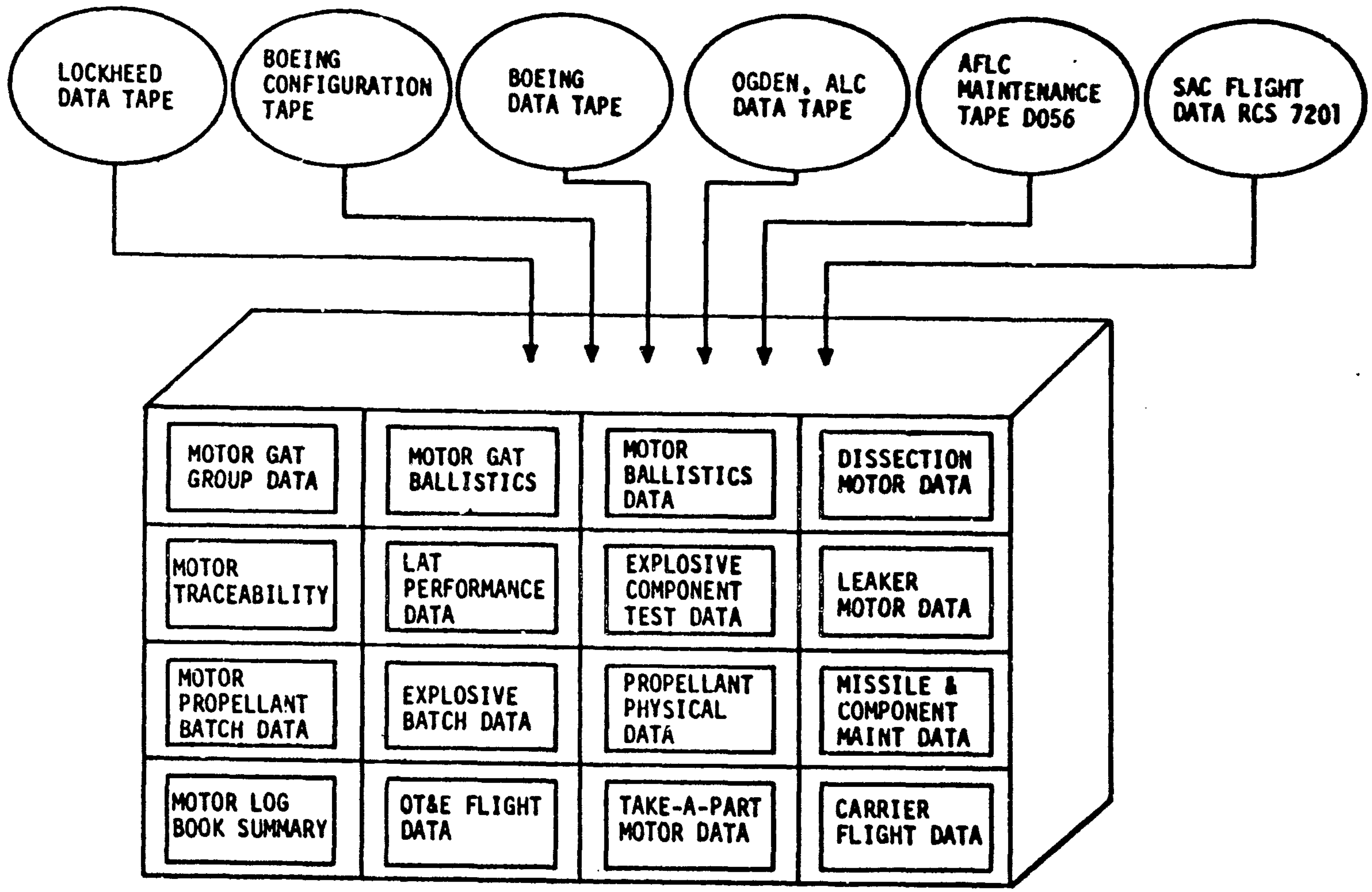


FIGURE 2-4 DATA STORAGE

3. Motor Supplier Test Data
4. Missile Operational Test and Evaluation Data
5. Surveillance Program Generated Data

2.5 Evaluation Criteria

The pre-test, post-test and other hardware evaluation criteria necessary to complete the evaluation package are discussed in more detail below:

A. Rocket Motor Evaluation Criteria

The criteria for evaluating aging of the motor hardware are contained in References 5 and 6 for the theoretical approach, Reference 7 for inspection of tested motors, and briefly described below:

1. Failure Limits

Ballistic parameter failure limits for use in determining the occurrence of age-out and in preparation of the SRAM motor service life estimate are contained in Reference 13. These parameters were listed in Table 2-2. Failure limits for the propellant physical properties and associated margins of safety are defined in D2AGM20162-1 "Stress Analysis Report".

2. Specification Limits

Specification limits are contained in Reference 31 for ballistic parameters, LPC Material Specification EMSU 001 for propellant physical properties and Reference 31 for the structural margins of safety. These specification limits may or may not be identical with failure limits.

3. Hardware Evaluation Criteria

Criteria for evaluating the integrity of motor hardware are contained in References 6 and 7. These reference documents identify age-sensitive items, suggest tests to reveal deficiences, and state the failure criteria for evaluating the component during an engineering inspection.

B. Component Evaluation Criteria

The three types of data to provide evaluation criteria used in developing service life estimates (SLE) for each explosive component are as follows:

1. Baseline (Time Zero) Data, retrievable from the computer data storage file, were defined in Section 2.4 and Appendix C. These data provide a baseline against which changes in functional performance of aged components are compared.

2. Surveillance Test Data are generated from component testing as described in paragraph 2.2 and Appendix C. These data, obtained from testing of service-aged components, show any trend in performance degradation which is age or use related.

3. Critical Values or Failure Limits are used to determine the limit of component performance for each test parameter which is evaluated in developing the service life estimate. In the absence of an evaluation program to determine failure limits, acceptance test and lot acceptance test criteria are used as critical values.

Component testing to provide the above data is of two types:

1. Non-destructive which may be repeated.

2. Functional (destructive) testing.

The test parameters on which service life estimates are based are given in Table 2-4. The performance (critical value) requirements are listed in Tables in Appendix C and are taken from each component's critical design specification.

2.6 SERVICE LIFE ESTIMATE - GENERALIZED STATISTICAL ANALYSIS PROCEDURE

2.6.1 Introduction

Initial program design requirements are levied contractually on most weapon system design contractors. These include requirements for service life, storage life, useful life and goals in terms of system, subsystem, and component reliability requirements. These are then used as a basis for determining the idealized reliability goals that explosive component surveillance programs must demonstrate.

However, designing a system for long service life is no guarantee that the system, subsystem, or component reliability will not degrade with age, therefore, it is necessary to verify thru testing that the quality and reliability of the system is not degrading with age.

In order to minimize the risk of age-out occurring without replacements being available, the item manager initially orders replacements based on the end of the component's initial design service life. He then periodically recomputes his replacement buy forecast requirements utilizing the current surveillance program's predicted service life estimate. However, in determining when replacements must be available the item manager must consider the budget lead time, the procurement lead time, the production lead time, and replacement lead time of the component. He must contract with industry for the replacement sufficiently ahead of the component life prediction to assure availability when the component life

expires. If the component's age life is five years, its replacement action must be initiated two years after the component was first delivered to the operational inventory, if it takes you three years to accomplish the replacement action.

Since the components for surveillance testing are usually only as old as the inventory components, an annual surveillance test performed at the two year age life should predict a minimum life of five years (which is three years ahead of the test data), in order to avoid unnecessary procurement of the replacement components. In the event the explosive component life prediction is wrong and age-out occurs sooner than expected; expedient change out is impossible because of low inventory stock level requirements and long component replacement times. Because of the longer lead times required for replacement, the item managers are requesting longer component life predictions which places a lot more responsibility on the engineer to make a better and longer estimate with more confidence. Because of cuts in program budgets and the inflation of the dollar, the engineer does not have available the alternative of doing more tests in order to have better confidence that longer range predictions can be achieved. He must do more and better analysis of the data from current tests.

In most statistical experiments a trade-off exists between the costs for obtaining additional data and the costs for analyzing the data. The costs associated with firing the SRAM motors/components are such that considerable effort should be devoted to analyzing the data. The general types of analysis which should be undertaken in making a service life estimate include testing the validity of assumptions, testing various methods for variance reduction, combining data from different sources, and finally the age trend analysis.

The requirement for the SRAM explosive component surveillance program is to demonstrate the reliability of components in the operational inventory periodically and to determine the expected component reliability at some point in time with a high degree of confidence for longer range predictions. The using command may want to know with 90% confidence that the tests will demonstrate that 90% of the inventory of aged motors/components will perform within the design envelope. The using command must also be advised on a timely basis when low reliability items must be replaced so the war plans and operations can be adjusted. Therefore, the following concepts must be considered:

A. A single approach to explosive component surveillance is not possible. Each individual item must be evaluated and the best approach to surveillance determined based on many factors: e.g., number and cost of explosive items, procurement lead time, point in time surveillance program is initiated, tests and test equipment costs, etc.

B. A surveillance program that is conceived as an integral part of a weapon system and planned from the start will be the least costly program to conduct. It will provide the most information with a minimum of risk in a timely manner.

C. A successful surveillance program utilizes data from all available sources. Among them are data from static test programs, flight tests and training launches, accelerated aging programs and laboratory component and material tests. These data are carefully analyzed and evaluated before component life recommendations are made.

D. Service life prediction by its very name implies prognostication into the unknown future.

Statistical prediction of the aging studies can be classified as variable analysis and attribute analysis. The basic tool in variable analysis is regression analysis. The measurable test data of the test specimens are plotted as a function of the age or other use parameters, and a degradation trend is established using the most suitable mathematical technique. Attribute analysis is used when the only available data is in the form of "go" or "no-go" (success or failure to function).

Regression analysis is a statistical analysis technique wherein data accumulated at various points in time are analyzed and a curve is fitted to them. Extrapolation of this curve into the future is the basis for predicting future component life. Tolerence limits are then placed around the regression curve and compared with predetermined critical component performance limits. If the regression curve tolerance limits do not exceed the critical failure limits at the desired future point in time, the component is usually assumed serviceable thru that time period. However, service life estimates reflect actual changes in a component as well as uncertainties in predicting the changes which can only be reduced by either collecting more data or by the use of more sophisticated procedures for analysis of the existing data. For the May 1974 service life estimate for the SRAM motor, the most cost effective approach was to refine and extend existing data analysis procedures. The major improvement in the statistical analysis procedures was the use of multidimensional statistical modeling techniques.

E. The regression analyses approach to component life predictions cannot be considered infallible. It can only be considered one of the factors necessary for sound judgment, and should be used with extreme caution after the design life has passed.

F. For the May 1974 service life analysis, there was no motivation to further refine the statistical analysis procedures (other than adding the multi-dimensional analysis procedures) since the estimated service life of the motor/components was acceptable. However, additional refinements are possible and should be considered for future service life analyses. These additional refinements (discussed in detail in Section V) would reduce some of the conservatism in the current procedures and thus would further extend the service life estimates.

2.6.2 General Procedure

The objective of the service life estimate procedure is to establish a standard methodology for handling and utilizing the available baseline (zero time) and subsequent surveillance test data with special consideration for the unique features associated with each particular component. The service life estimate procedure than predicts the minimum service life of the particular component.

The required evaluation/test criteria which will be used to estimate the service life were presented in Section 2.5. Test parameters which are considered to be critical and those which are considered to be supporting information are summarized in Tables 2-2, 2-3 and 2-4.

The general procedure for establishing and evaluating the service life of SRAM motors/components consists of projecting each predictive parameter mean value and selected confidence band. Advanced predictions that consider replacement time were made by extrapolation beyond the demonstrated age data points into the real life unknown prediction regime. The hardware will be evaluated for degradation and signs of "early age-out". Age-out is indicated when the predicted trend line crosses the specification or other established criteria limit. The conservatism associated with the determined age-out alert limits can be evaluated knowning the specification requirements and the estimates of the actual or critical failure point or limit. The SRAM SLE statistical analysis techniques were developed to eliminate the data scatter resulting from differences in component test conditions and to incorporate multidimensional regression analysis techniques.

The SRAM statistical data analysis results in the 2 Dimensional final format for the SRAM motor/components is as shown in Figure 2-5. Motor/component performance parameters such as pressure and thrust as a function of age are used to determine the age trend line and the tolerance bands (reliability with confidence level) for the trend line assuming a good trend line prediction is possible. (Figure 2-6).

Figure 2-7 shows the general flow chart of the procedure for estimating the service life. Preliminary estimates of the service life estimate will be made using acceptance (zero time) test data. First year and subsequent surveillance test data will be used to upgrade the initial regression equations to obtain more accurate estimates of the service life.

2.6.3 Statistical Analysis

A. Statistical Modeling

The major statistical computational operations and data flow for analysis of the SRAM component data are shown in Figure 2-8. A

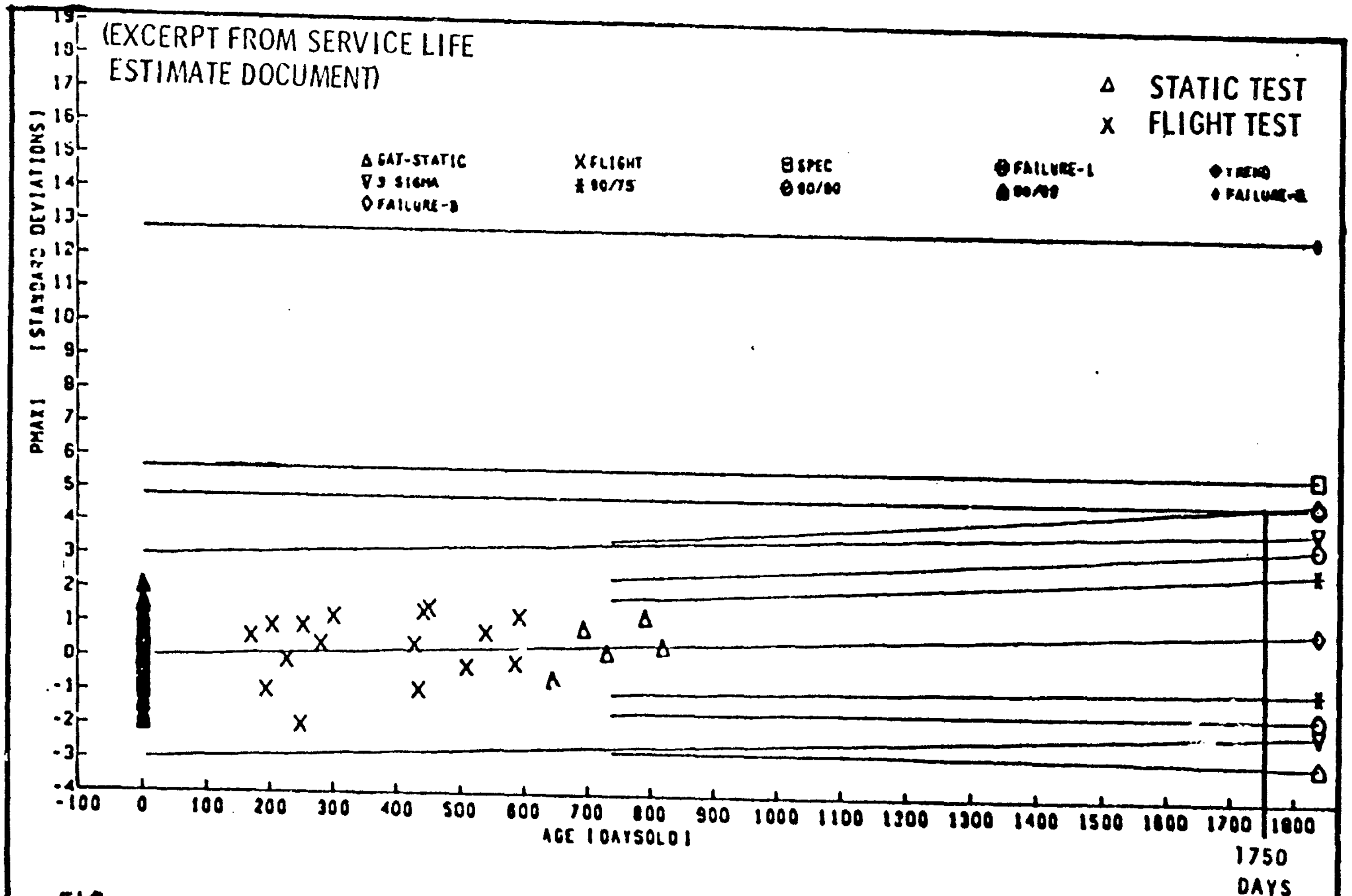
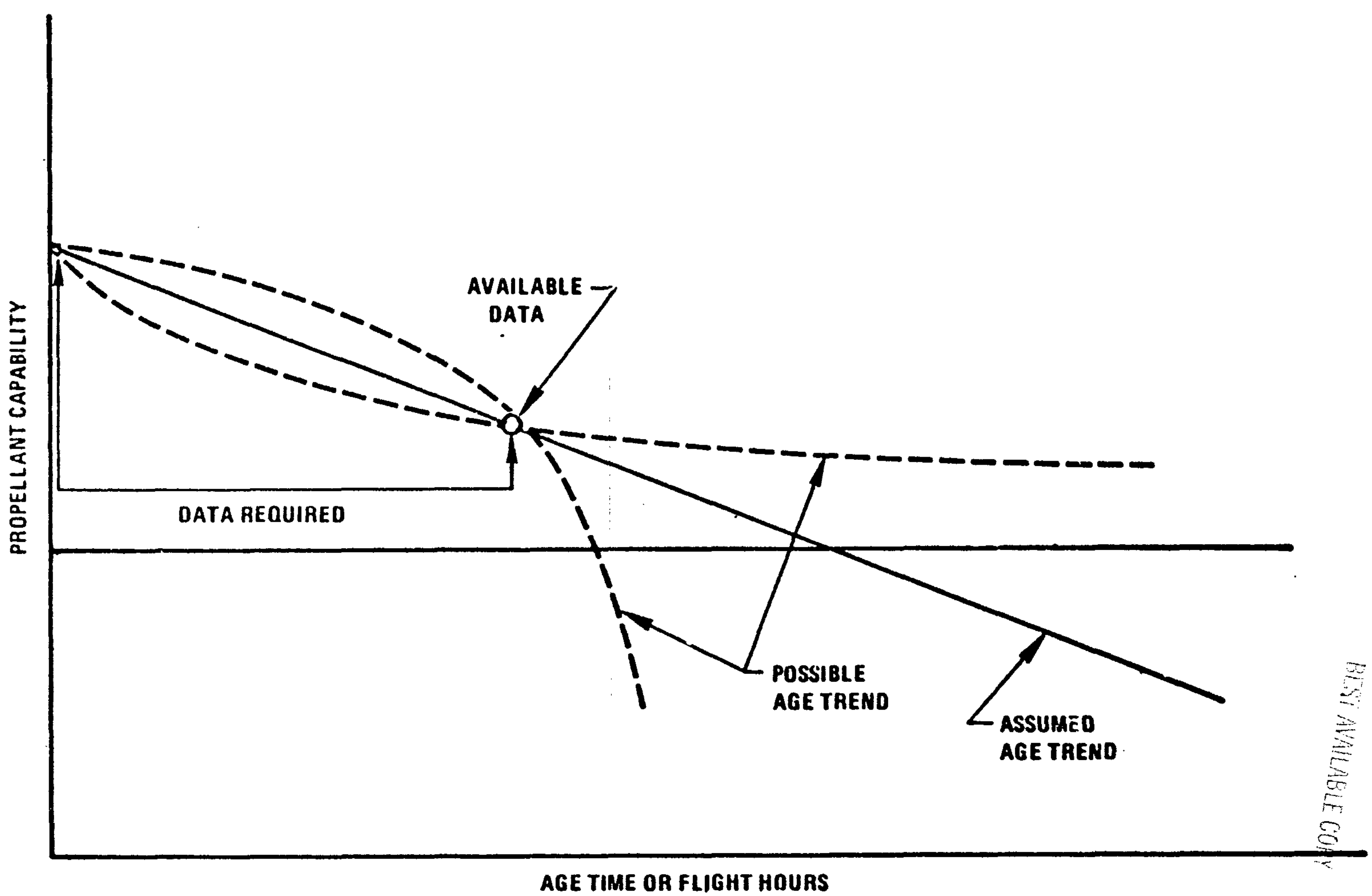


FIG. 2-5

SRAM PLOT

FIRST PULSE MAX. CHAMBER PRESSURE/CALENDAR AGE REGRESSION USING SAMPLE MAX PROPELLANT BURN RATE

AGING TRENDS FOR SRAM MOTOR
FIGURE 2-6



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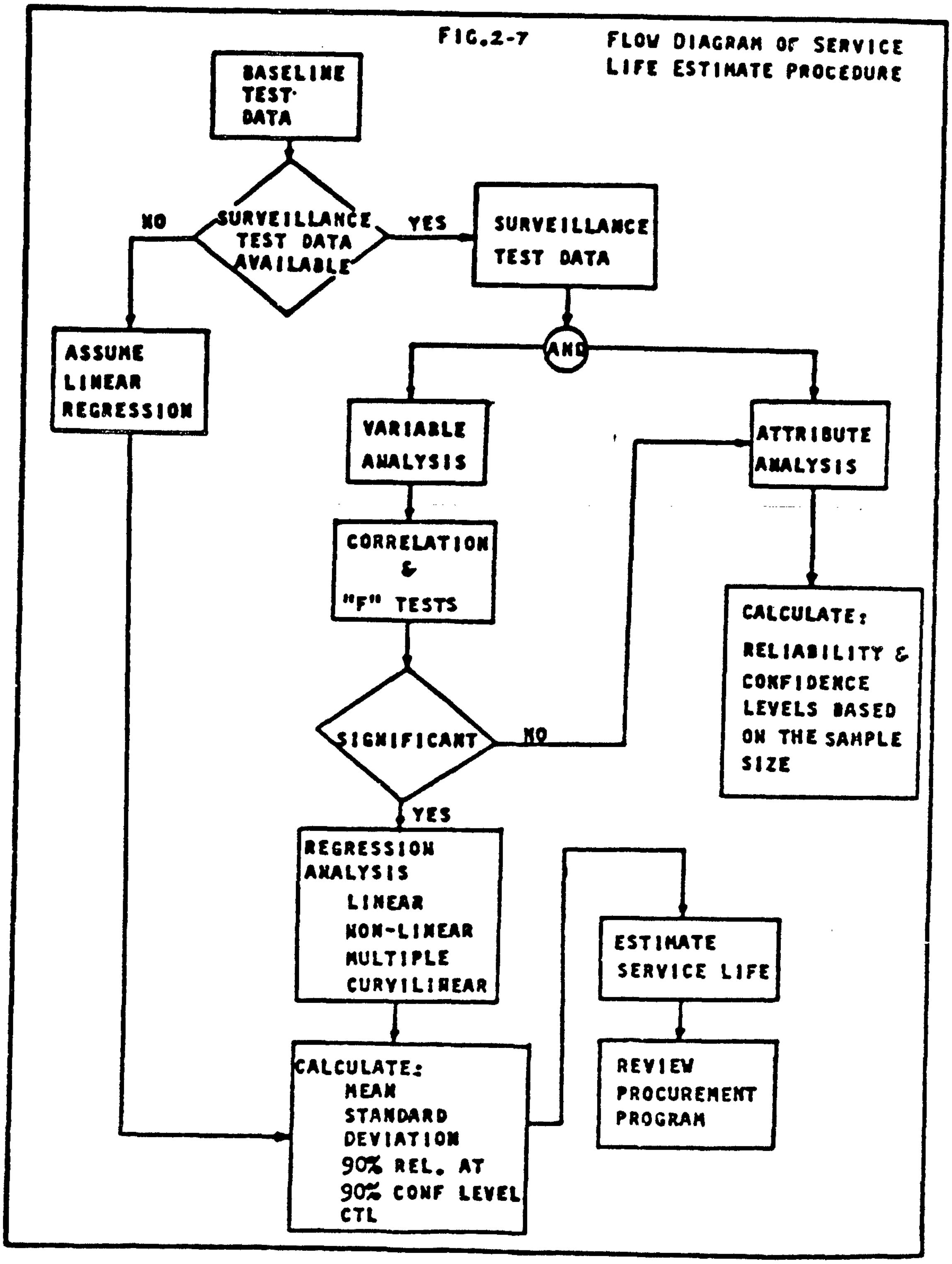
FIG.2-7
FLOW DIAGRAM OF SERVICE LIFE ESTIMATE PROCEDURE
BASELINE TEST DATA
SURVEILLANCE TEST DATA AVAILABLE
NO
YES
SURVEILLANCE TEST DATA
ASSUME LINEAR REGRESSION
AND
VARIABLE ANALYSIS
ATTRIBUTE ANALYSIS
CORRELATION & "F" TESTS
CALCULATE: RELIABILITY & CONFIDENCE LEVELS BASED ON THE SAMPLE SIZE
SIGNIFICANT
NO
YES
REGRESSION ANALYSIS
LINEAR
NON-LINEAR
MULTIPLE
CURVILINEAR
ESTIMATE SERVICE LIFE
CALCULATE:
MEAN
STANDARD DEVIATION
90% REL. AT
90% CONF LEVEL
CTL
REVIEW PROCUREMENT PROGRAM

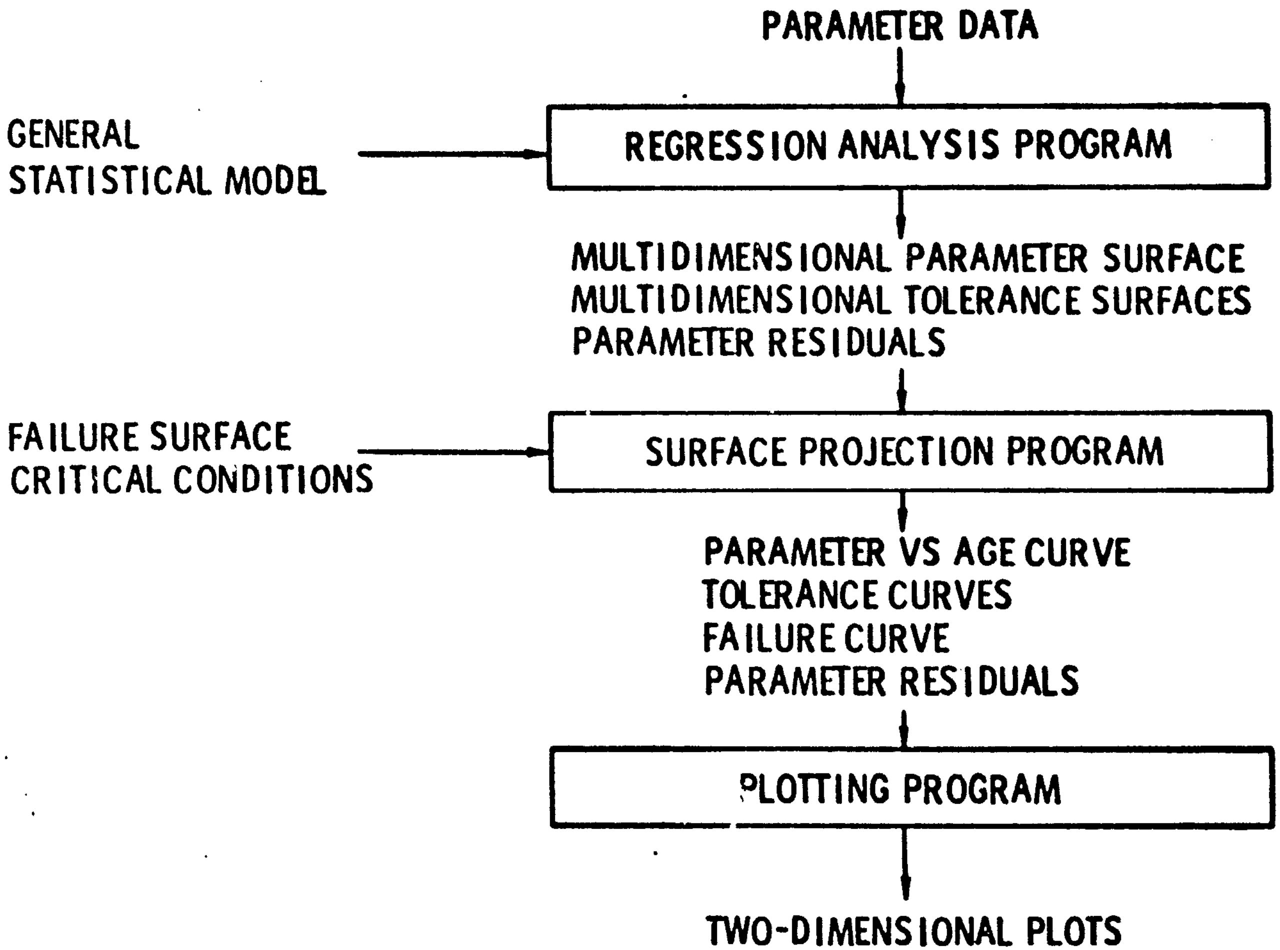

FIGURE 2-8 MAJOR COMPUTATIONAL STEPS FOR DATA ANALYSIS

generalized statistical model is developed which relates a performance parameter such as thrust to characteristics such as firing temperature and propellant burn-rate.

The primary reasons for using statistical modeling procedures in the analysis of the SRAM data is to reduce data scatter (Data normalization, Data grouping comparisons, and Data Bias removal) and to compare and evaluate test data for motors/components fired at different temperatures. The modeling procedures reduce the spread in the tolerance surfaces and thus allow for the extension of the service life estimates for the missile motor/components.

A stepwise multiple linear regression program was generated to use the parameter data to determine which of the terms in the generalized model are statistically significant. When a specific statistical model for the performance parameter has been determined, the tolerance surfaces for this statistical model are established. A three-dimensional example of the multidimensional surfaces used in the data analysis is shown in Figure 2-9. For this example the performance parameter is closest to the failure limit for the high temperature firings and thus the critical condition here is the high firing temperature. The next stage in the computational process is the conversion of this multidimensional information into two-dimensional information which can be displayed on two-dimensional plots as in Figure 2-5.

The reasons for developing two-dimensional plots of multidimensional surfaces and data are: (1) a visual presentation is more easily evaluated and interpreted than the equations for the various surfaces and (2) visual interpolation to determine the confidence levels for the tolerance curve which intersects the parameter failure limits at five years (and the equivalents in flight hours, etc.) was much simpler than the development of a computer program to perform this task.

The information required to develop the plots is: (1) the mean value surface (statistical model), (2) the tolerance surfaces, (3) the actual parameter values or the residuals, (4) a parameter failure surface, and (5) critical or worst case conditions for all of the independent variables except age.

Descriptions of the elements in the data analysis follow and are contained in detail in Appendices A, B and C.

The age at which a tolerance curve and a failure limit intersect is dependent on: (1) actual changes in the performance parameter with age, and (2) the spread of the tolerance band. The tolerance band spread is in turn, dependent on sample size and the magnitude of the data scatter. The goal in the development of the SRAM procedures was to minimize the spread in the tolerance bands so that actual changes in the performance parameters could be more easily detected. The two-dimensional regression analysis

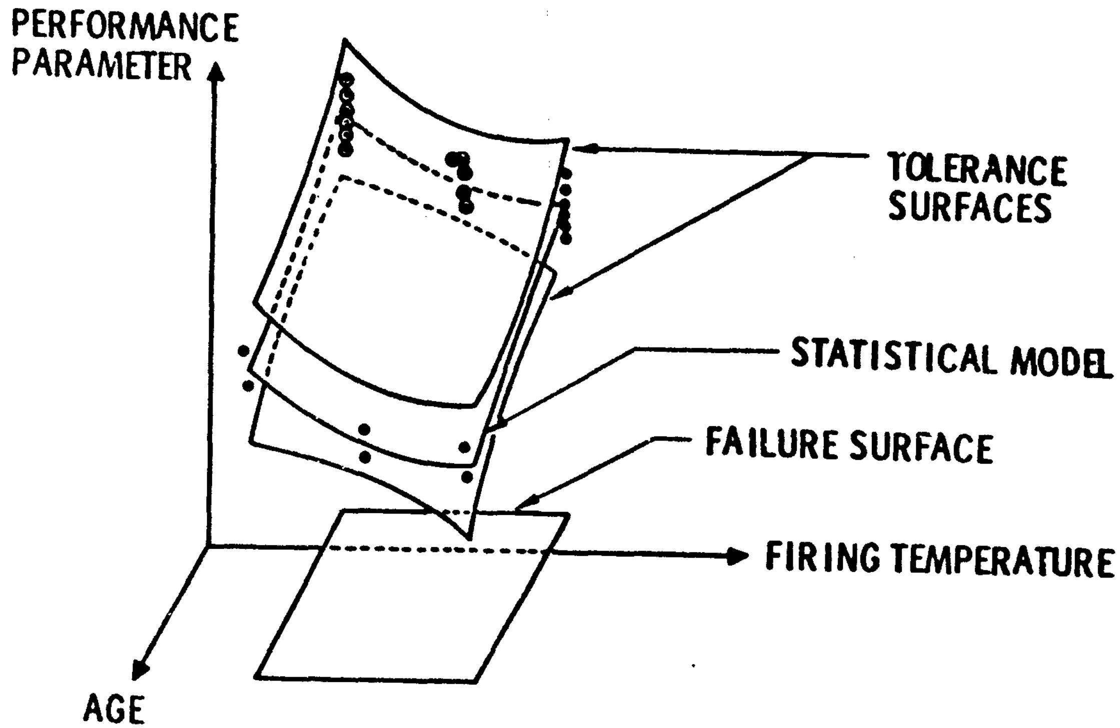

FIGURE 2-9
MULTIDIMENSIONAL SURFACES
FOR
TWO-DIMENSIONAL PLOTTING

used previously (References 2, 3 and 4) was extended to multi-dimensional analysis so that data from components fired at different temperatures (Figure 2-10) could be combined (increasing sample size) and so that known characteristics of a component could be used to reduce data scatter. The benefit derived from the multidimensional analysis is an extension of the service life estimates. For example, the 90/99 tolerance curve for the motor first pulse maximum chamber pressure intersects the failure limit at 1000 days when two dimensional analysis is used and intersects the failure limit at 1750 days when multidimensional analysis is used (Figure 2-5). The improved results with the multidimensional analysis are a consequence of using zero age propellant strand burn-rate to reduce data scatter and of combining motors fired at different temperatures. Combining the data for different temperatures permitted the use of the OT&E flight data and increased the sample size.

Tables 3-2, 3-3 and 3-5 and Tables in Appendices B and C summarize the critical test parameters which are considered, a-prior, to be primary failure parameters and other parameters which are considered to provide supporting information of the regression behavior. This summary may require revision based on data obtained during the surveillance tests. In the absence of identifiable regression trends, other statistical methods were applied and the results analyzed to provide a statement of service life, and/or reliability estimates. The planned annual service life estimate will be presented in logic form, in the detail of the plot form shown on Figure 2-5. A family of plots are provided for each of the aging parameters being evaluated in Reference 8.

The statistical model eventually chosen by the regression program depends on: (1) the true functional relation between the dependent variable and the independent variables, (2) the values of the independent variables for which observations are taken, and (3) the total number of observations. The first item requires no explanation. The second item is discussed at length in tests on the design of experiments (References 9 and 10 of Reference 14). Theoretically, the number of observations required to develop a statistical model is equal to the number of terms in the model. However, in practice it is found that at least three to five observations are required for each term in a statistical model.

The major advantage of statistical modeling techniques is that an approximating function can be developed with little or no information about the true functional relation. Unfortunately, this approximating function is valid only for the range of the independent variables actually used in developing the model. Extrapolations beyond this range may or may not be valid. Any additional assumptions made during the analysis should also be tested for validity. If standard statistical procedures are not appropriate for these tests, then the possibility of empirically deriving test procedures using computer simulations should be investigated.

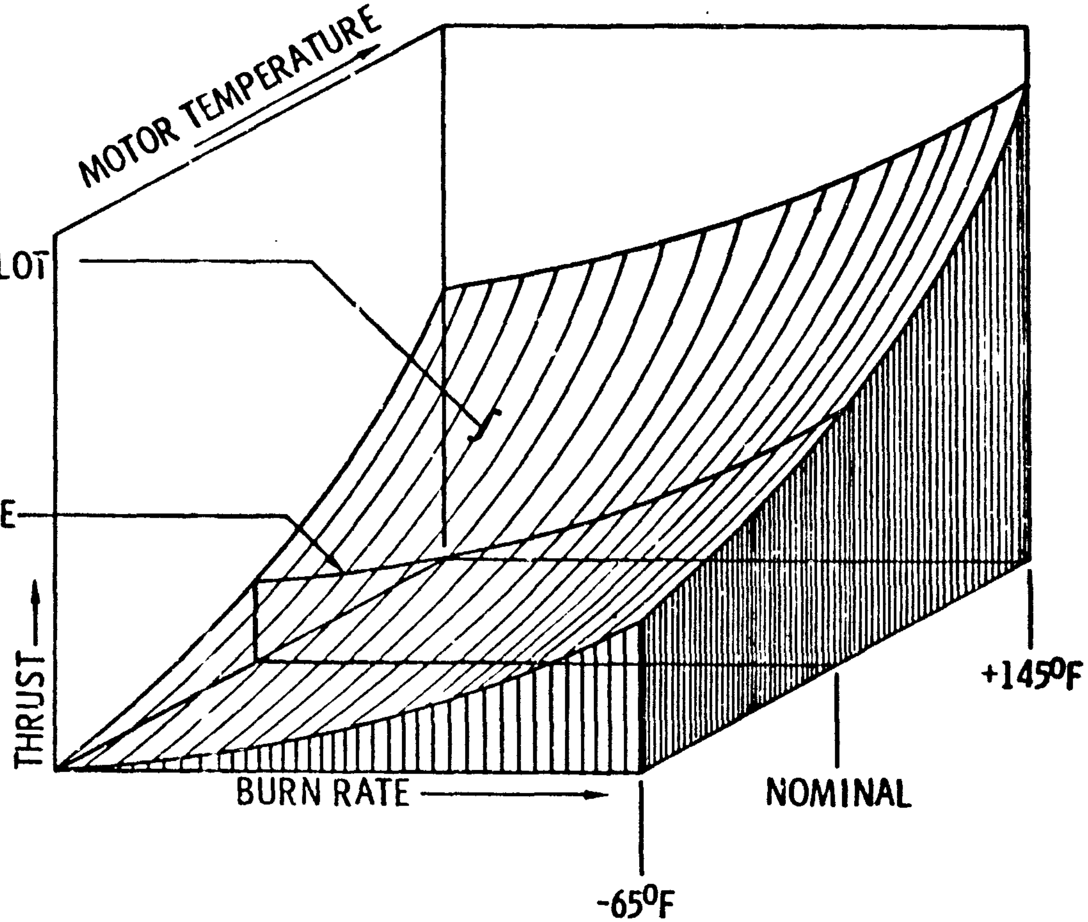

FIGURE 2-10 SRAM / MINUTEMAN FUNCTIONAL RELATIONSHIPS

B. Tolerance Surfaces

Tolerance surfaces express the uncertainties in the statistical models and the scatter in the parameter residuals. A reliability and a confidence level are associated with the tolerance surfaces. The reliability reflects the scatter in the parameter residuals and the confidence level reflects the statistical uncertainties in the model. The tolerance surfaces are dependent on the probability distribution of the random errors in the data used to derive the statistical model. In developing tolerance surfaces, it is usually assumed that the random errors have the normal (or Gaussian) distribution. The validity of this assumption should be tested before confidence levels and reliabilities are assigned to a tolerance surface.

C. Failure Limits

The determination of the intersection of a tolerance curve and a failure limit becomes more complex as the dimensionality of the statistical model of the performance parameter increases. For a two-dimensional model (Figure 2-5) (parameter vs. age), the failure limit/tolerance curve intersection is a single point. The failure limit/tolerance surface intersection is a curve for a three dimensional model and is a surface (or hypersurface) for a model of four or more dimensions. (Figures 2-9, 2-10 and 2-11).

Worst case conditions were used to determine the intersections for the May 1974 service life estimate. For example, the intersection of the failure limit and the tolerance curve for a particular motor/component parameter was determined for the maximum firing temperature and the maximum observed propellant burn-rate. The use of the worst case conditions in determining failure limit/tolerance curve intersections leads to conservative estimates of the service lifes of the motor/component. The plots shown in Reference 8 are for worst case conditions and thus, the only statement which can be made regarding these tolerance curves is that if all motor/components are fired at their extreme temperature and if all had the extreme observed burn-rate, then 90% of the motors/components will be within the tolerance band with the specified confidence (see Figure 2-12). It is known that the propellant burn-rates would move the failure limit away from the trend line and extend the estimated service life (or increase confidence level) of the component. Similarly, use of firing temperatures which would be experienced in the field would further extend the service life.

D. Special Procedures

Several special statistical procedures were used in the analysis of the SRAM motor data. These are: (1) burn-rate smoothing, (2) prediction of chamber pressure for flight tests, and (3) bias removal for the flight test data, and are described in detail in Appendix B.

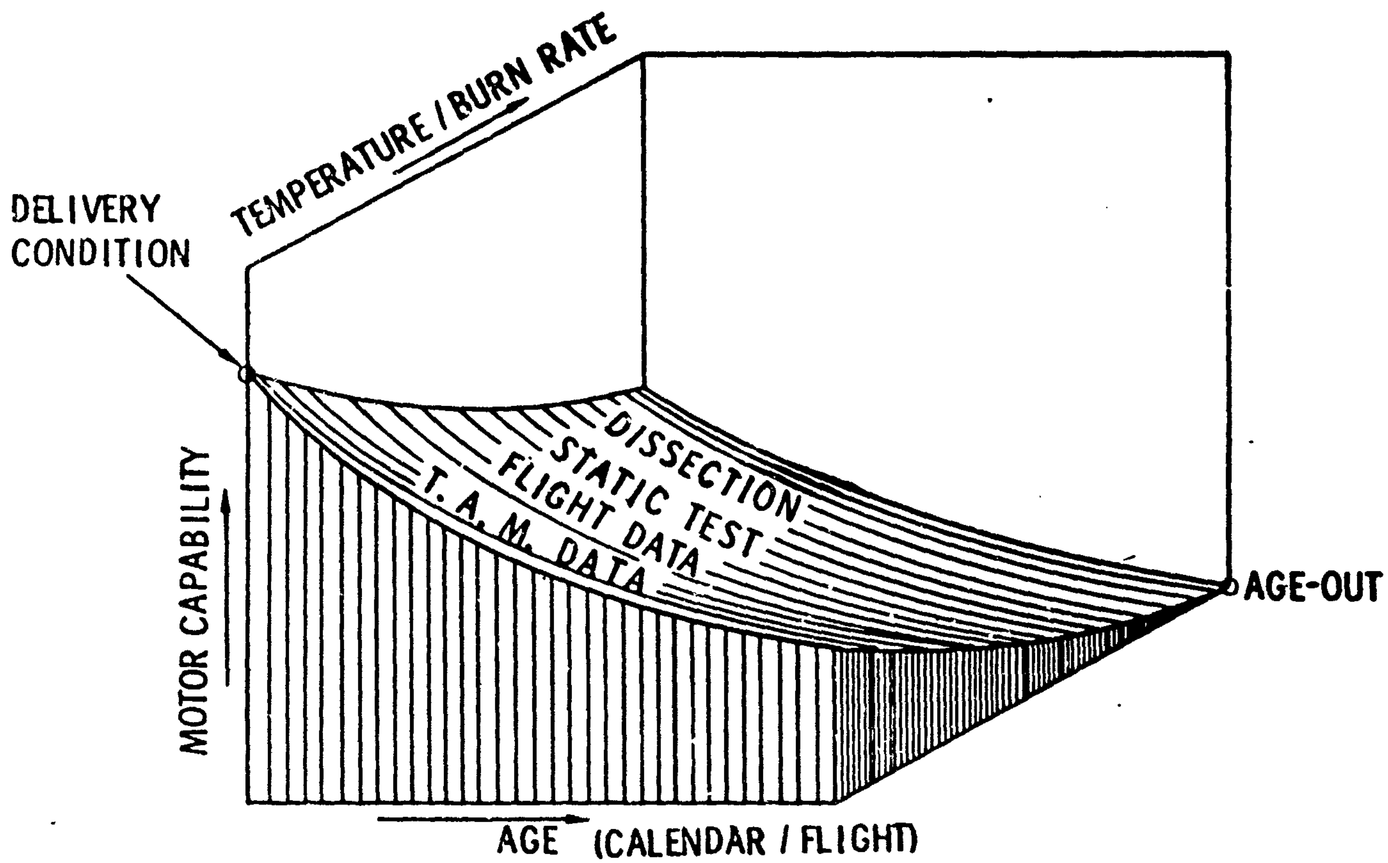

FIGURE 2-11 DETERMINATION OF SERVICE LIFE

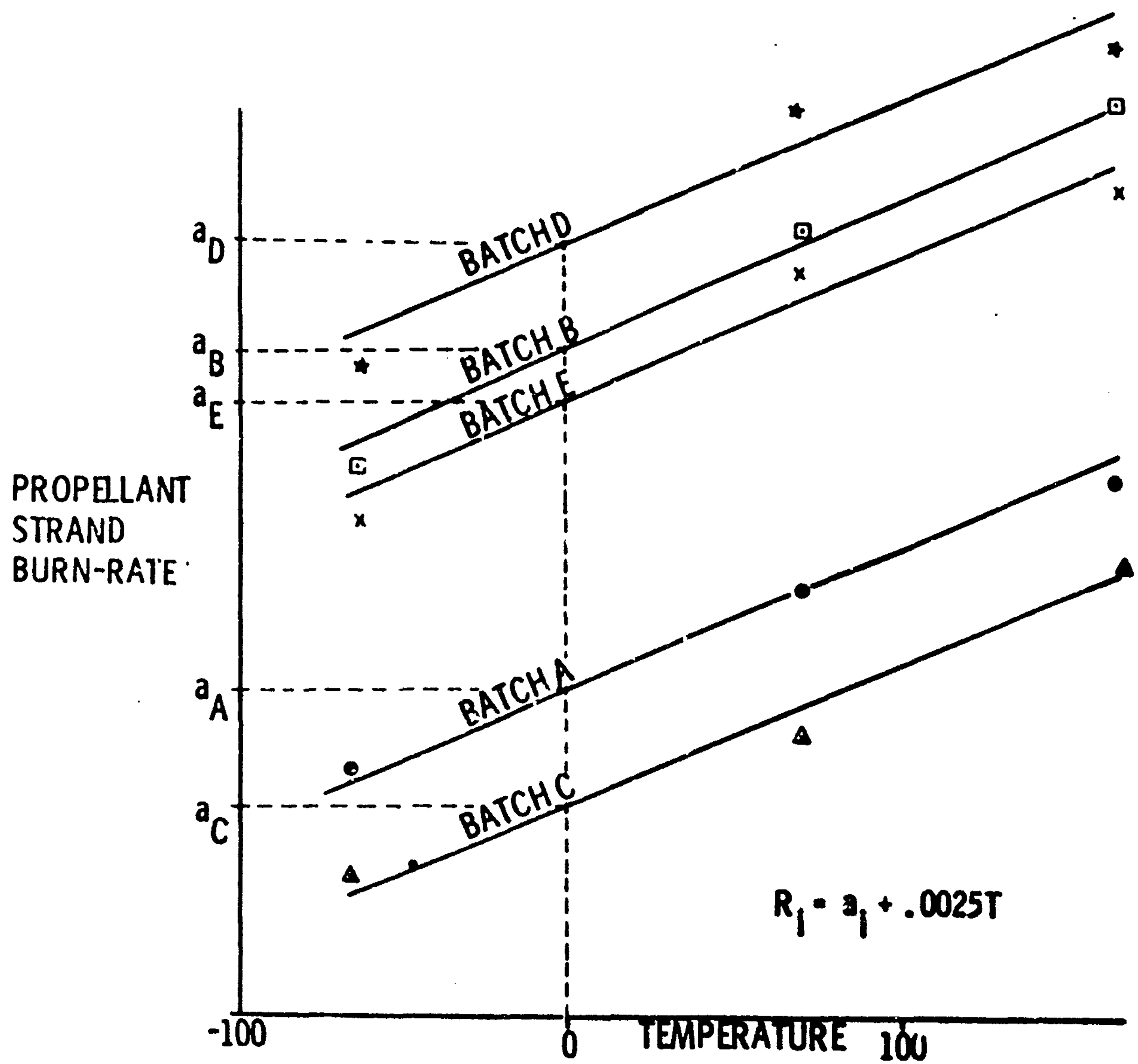

FIGURE 2-12 STATISTICAL MODEL FOR BURN-RATE SMOOTHING

SECTION III

FINDINGS

3.0 GENERAL

Procedures for estimating service life for the SRAM rocket motor and ordnance devices were used in accordance with Reference 5, where surveillance test data are available. Results from statistical regression analyses are plotted against relevant aging parameters in conjunction with zero time data and limits (3σ, 90% probability and 90% confidence, failure, etc.). For subsystems where surveillance testing has not been accomplished, statistical analyses could not be conducted. In these cases, the format for reporting results is the same with only the zero time data and limits plotted.

During each year of the Surveillance Program, five (5) rocket motors extracted from missiles in the SAC field inventory, are to be static fired. Two (2) rocket motors from the field inventory are to be chemically dissected annually to allow physical/ballistic property tests on the motor propellant. Twenty-two (22) each of the ordnance devices (Missile Ejector Cartridge, Fin Unlock Squib, Igniter Pressure Cartridge, Battery Gas Generator Squib, Battery, and Electrical Cable Switch Assembly) are to be tested each year.

This year, five field motors ranging in age from 639 days to 817 days old, and in flight hours from 49 hours to 195 hours, were successfully static fired. However, only one field motor had completed dissection and undergone propellant testing in time to support this years Service Life Estimate. The Missile Ejection Cartridges were the only Aged-components tested in time for the FY74 Service Life Estimate. The other Ogden ALC baseline testing was completed for all the components except the Electrical Cable Assembly Switch.

3.1 SERVICE LIFE ESTIMATE FOR ROCKET MOTOR

Estimation of the SRAM rocket motor service life is developed from analysis of motor data and a hardware assessment. Analysis of the data is contained in Section 3.1.1. A statement of the service life estimate is contained in Section 3.1.3, which summarizes the age-out effects discussed in detail in Sections 3.1.1 and 3.1.2. Reference 5 presents the procedures for estimating the service life of SRAM. The ballistic and structural parameters are given in Tables 2-2 and 2-3.

3.1.1 Data Analysis

A. <u>Exposure Data</u>

The age and flight exposures experienced by the OT&E

flight motors and the Ogden Air Logistics Center surveillance motors are shown in Table 3-1 and Figure 3-1 presents a typical history.

Five age or exposure considerations were used. They are: calendar age (days old), total flight hours below 15,000 feet, total flight hours, total number of external carries and total number of carries. The point of major interest on each calendar age regression plot is the confidence limit value for 90% of the population being within the true failure limit at five years. For each of the other age considerations of flight exposure, a five year equivalence was determined by applying the ratio of the calendar five year/age oldest data point to the oldest data point. This extrapolation is based upon the utilization displayed by the sample analyzed. Each year this utilization rate is expected to change with the major changes anticipated during the early years. For the Fiscal Year 1974 service life estimate, the following values were used:

Age/Exposure	Oldest Data Point	Five Year Equivalence
Calendar age, days	819	1826
Flight hrs 15,000 ft.	34.2	76.2
Total flight hours	161.7	360.4
External carries	14	31.2
Total carries	18	40.1

B. Ballistic Data/Parameters/Regression

Table 2-2 lists the ballistic parameters and tests that were selected for regression to support the service life estimate. They are defined in Section 2.0. The numerical values of all failure limits are contained in Reference 12, and their derivations are in Reference 13. Caution must be exercised in data handling because motor performance is classified confidential and missile performance secret.

Parameter units used for regression, herein, are standard deviations from GAT mean performance. The reasons for using standard deviations are contained in Reference 5. In summary, this technique was selected so that motors built with different burn rate propellants and fired at different motor temperatures could be compared to one another. The numerical values of all input data to the regressions are contained in Reference 12 and will also be stored in the Surveillance Data Storage and Retrieval System. The procedures used to generate the regressions are documented in Reference 14. The resulting regressions were presented in Figures 4.1-15 through 4.1-64, Reference 5, and summarized in Table 3-2. The standard deviations (unexplained variations) of the GAT population and the square of the multiple correlation coefficient (percent of variability explained by regressions) are shown in Table 3-3.

TABLE 3-I MOTOR DATA

USE	AIRPL	MISSILE SERIAL NUMBER	MOTOR SERIAL NUMBER	MOTOR FIRING TEMP	PROP BATCH NUMBER	BURN RATE, IN/SEC -65°F	BURN RATE, IN/SEC 70°F	BURN RATE, IN/SEC 165°F	SAC BASE	AGE: DATE FIRED	AGE: DATE CAST	AGE: DAYS OLD	AGE: CARRIES INT	AGE: CARRIES EXT	AGE: CARRIES TOTAL	AGE: FLIGHT HOURS < 15000	AGE: FLIGHT HOURS > 15000	AGE: FLIGHT HOURS TOTAL
OGDEN ALC TRAINING	- -	- -	- -	-65	240	1.99	2.30	2.50	- -	12-19-73	2-3-72	685	- -	- -	- -	- -	- -	- -
OGDEN ALC SURVEILLANCE FIRINGS (5)	- -	71-928	41	-65	214	1.98	2.32	2.58	LORING	1-17-74	11-17-71	792	14	0	14	31.4	102.6	134.0
	- -	71-930	70	-65	236	1.95	2.27	2.52	LORING	1-24-74	1-24-72	731	15	3	18	34.2	122.0	156.2
	- -	72-632	134	145	276	1.94	2.26	2.51	SAWYER	1-30-74	4-24-72	646	0	6	6	12.9	36.1	49.0
	- -	71-942	12	-65	189	1.92	2.25	2.45	LORING	1-10-74	10-14-71	819	12	0	12	19.5	85.0	104.5
	- -	71-973	98	70	254	1.98	2.31	2.56	LORING	1-31-74	3-7-72	695	0	9	9	21.8	49.7	71.5
EARLY PRODUCTION LAUNCH	B-52	71-926	052	65	220	1.97	2.29	2.51	LORING	6-15-72	12-7-71	190	5	0	5	15.6	36.3	51.9
LORING OPERATIONAL TEST AND EVALUATION (17)	B-52	71-912	034	37	211	1.97	2.31	2.54	LORING	1-9-73	11-4-71	432	5	0	5	11.0	36.8	47.8
	B-52	72-654	162	55	275	1.99	2.29	2.55	LORING	1-23-73	4-19-72	279	5	0	5	14.6	29.6	44.2
	B-52	71-915	039	52	213	1.92	2.24	2.50	LORING	2-6-73	11-15-71	449	1	2	3	8.0	20.7	28.7
	B-52	72-727	232	48	324	2.04	2.33	2.60	LORING	3-6-73	8-2-72	216	4	0	4	7.0	37.8	44.8
	B-52	71-959	082	25	237	1.98	2.31	2.54	LORING	3-27-73	1-26-72	426	0	11	11	27.0	70.2	97.2
	B-52	71-968	088	63	241	1.98	2.33	2.56	LORING	4-18-73	2-2-72	441	16	0	16	24.4	137.3	161.7
	B-52	72-723	248	59	332	1.88	2.22	2.50	LORING	4-24-73	8-21-72	247	8	0	8	12.6	66.8	79.4
	B-52	71-950	046	60	218	1.96	2.30	2.55	LORING	5-22-73	11-30-71	539	6	0	6	17.7	34.4	52.1
	B-52	72-844	351	60	378	1.95	2.29	2.56	LORING	5-30-73	11-2-72	190	6	0	6	13.0	47.1	60.1
	B-52	72-843	350	47	377	1.96	2.31	2.54	LORING	6-5-73	11-16-72	201	3	1	4	12.5	22.4	34.9
	B-52	72-803	314	40	357	1.92	2.28	2.53	LORING	6-13-73	10-5-72	251	0	6	6	22.3	35.9	58.2
	B-52	72-759	262	45	336	2.00	2.32	2.55	LORING	6-20-73	8-24-72	300	10	1	11	21.7	76.7	98.4
	B-57	71-917	042	48	215	2.00	2.34	2.60	LORING	7-3-73	11-18-72	593	11	2	13	31.9	88.5	120.4
	B-52	72-860	369	70	382	1.98	2.32	2.57	LORING	7-11-73	11-29-72	224	5	0	5	15.3	26.2	41.5
	B-52	72-929	442	74	407	1.92	2.26	2.56	LORING	7-18-73	1-31-73	168	1	2	3	6.7	21.5	28.2
	-52	71-974	090	45	251	2.00	2.30	2.60	LORING	7-24-73	3-1-72	510	0	2	2	2.5	18.8	21.3
	B-52	71-938	055	40	227	1.96	2.30	2.56	LORING	7-31-73	12-23-71	586	0	14	14	29.5	108.6	138.1
OGDEN ALC DISSECT (2)	- -	71-916	036	- -	197	2.00	2.36	2.57	LORING	11-29-73	11-11-71	740	11	16	27	84.7	151.6	236.3
	- -	72-630	133	- -	276	1.94	2.26	2.51	LORING	2-22-74	4-24-72	669	3	20	23	49.6	159.4	209.0

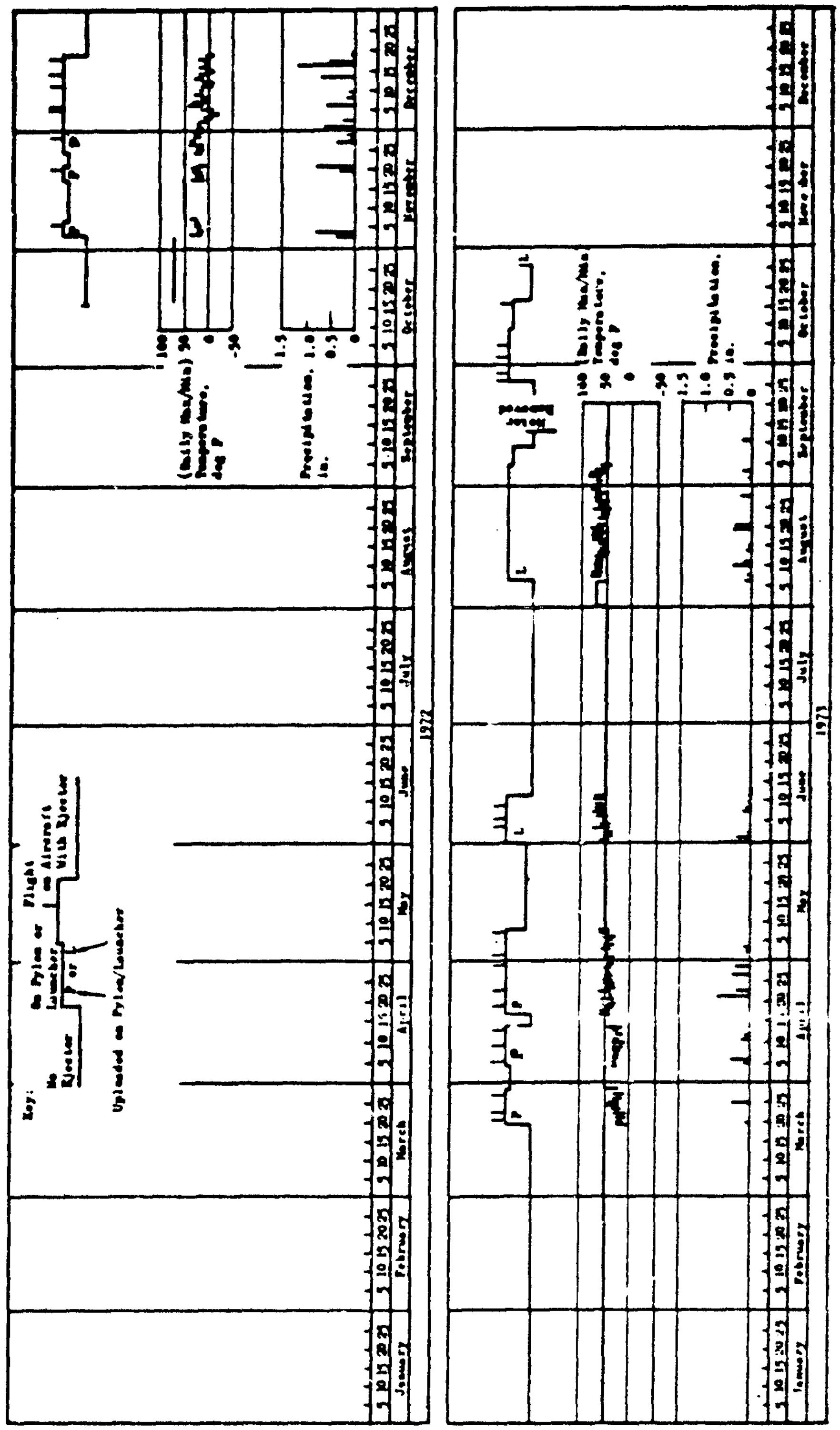

FIGURE 3-1 ROCKET MOTOR OPERATIONAL USAGE HISTORY

TABLE 3-2

SRAM MOTOR - RESULTS OF REGRESSION ANALYSES

CONFIDENCE THAT 90% OF THE POPULATION IS WITHIN FAILURE LIMITS AT OR EQUIVALENT TO 5 YEARS OF AGE

BALLISTIC PARAMETER	CALENDAR AGE		FLT HOURS <15,000		TOTAL FLT. HOURS		EXTERNAL CARRIES		TOTAL CARRIES	
	1	2	1	2	1	2	1	2	1	2
$P_{MAX\ 1}$	<50	99	<50	96	<55	99	<50	94	<50	97
$F_{AVG\ 1}$		>99		>99		>99		>99		>99
$T_{START\ 1}$		81 T		95 T		83 T		93		83
$T_{END\ 1}$		>99		>99		>99		>99		>99
$I_{T\ 1}$		>99		>99		>99		>99		>99
$P_{MAX\ 2}$		94		>99		>99		>99		>99
$F_{AVG\ 2}$		>99		>99		>99		>99		>99
$T_{START\ 2}$		>99		>99		>99		>99		>99
I_{TM}		>99		>99		>99		96		>99

1 Specification Propellant Min/Max Burn Rates

2 Sample Population Min/Max Burn Rates

T Regression has significant (5% level) trend towards failure limit.

TABLE 3-3

SRAM MOTOR - PERCENT OF VARIABILITY EXPLAINED BY REGRESSIONS

BALLISTIC PARAMETER	STANDARD DEVIATION GAT POPULATION	PERCENT OF VARIABILITY EXPLAINED BY REGRESSION				
		CALENDAR AGE	FLT. HRS. < 15,000	TOTAL FLT. HRS.	EXTERNAL CARRIES	TOTAL CARRIES
$P_{MAX\ 1}$	54.2 psi	0.97	0.97	0.97	0.97	0.97
$F_{AVG\ 1}$	83.4 lbs	0.99	0.99	0.92	0.99	0.99
$T_{START\ 1}$	0.061 secs	0.97	0.97	0.97	0.97	0.97
$T_{END\ 1}$	1.134 secs	0.99	0.99	0.99	0.99	0.99
I_{T1}	540 lb-secs	0.85	0.85	0.86	0.85	0.85
$P_{MAX\ 2}$	92.6 psi	0.91	0.91	0.91	0.91	0.91
$F_{AVG\ 2}$	180 lbs	0.96	0.96	0.96	0.96	0.96
$T_{START\ 2}$	0.167 secs	0.73	0.72	0.71	0.69	0.72
I_{TM}	986 lb-secs	0.90	0.89	0.89	0.89	0.89

During the process of determining true failure limits, it was decided that the parameters impacting missile system failure limits could, in three cases, be defined by more meaningful ballistic parameters then those specified in the Reference 5. The three ballistic parameters to be re-defined are ignition time (first and second pulse), first pulse thrust decay time, and first pulse impulse.

The true failure limit from the missile perspective for the ignition time of the first pulse was determined to be 1.9 seconds and for the second pulse 4.0 seconds. These values are not compatible with the requirement for attaining 75% of motor pressure at 2 seconds as used in the definition of ignition time (Table 2-3 and Reference 5). To resolve the problem, a new ballistic parameter called "start time" has been derived. "Start time" is defined as the time from the ignition signal to the time 1100 psia is attained during pressure rise and is used in the regression analysis in place of ignition time.

First pulse thrust decay time, time from the end of burn time to the end of action time, is a parameter to monitor thrust decay. Assurance that first pulse operation is concluded prior to second pulse ignition is not provided by this parameter alone. The realistic requirement is that operation of the first pulse be completed by a specific time. Accordingly, a new ballistic parameter, first pulse end time, has been defined as the time from first pulse ignition to the end of action time. Therefore, first pulse end time is used for the ballistic parameter to indicate completion of first pulse operation as a regression candidate instead of first pulse thrust decay time.

The true failure value of first pulse total impulse from a warhead arming perspective is a function of the absolute impulse value - not the manufacturing specification value expressed as percent of total motor impulse. Therefore, the definition of first pulse impulse has been re-defined to absolute impulse in the first pulse over the action time instead of a percentage of total motor impulse.

In plotting the dependent variable specification and true failure limits, a decision had to be made as to what limiting propellant burn rate to use. A review of the sample population studied, however, revealed that the actual minimum burn rate was 1.88 in/sec at -65°F and the actual maximum was 2.62 in/sec at 165°F. As can be seen from Table 3-2, the use of more realistic values substantially improved the confidence that the motor was good for five years from ballistic considerations. At some future time when production of the entire fleet is complete, it is recommended that consideration be given to using the 95 percentile burn rate. Discussion of the separate dependent variable regressions are presented in Reference 12.

C. Physical Property Data/Parameters/Regressions

As indicated in the Surveillance Program Implementation Plan (Reference 5), the first Service Life Estimate should have included data from two dissected field motors (S/N AHS-0036 and S/N AHS-0133), from the dissection of 41A22-020B, from one segment of TAM 41A34-0005, and from two segments of TAM 41A35-0002, and from the TAM zero time cartons. The data contained herein, based on the tests presented in Table 2-3, is from motor AHS-0036, the only dissection data officially released to date. Margin of safety trending cannot be accomplished based on one data point.

Motor Shore "A" Hardness

The general characteristics of motor AHS-0036 propellant were evaluated by Shore "A" Hardness measurements taken immediately after the propellant segments were dissected from the rocket motor. Extensive measurements were made on slices of propellant from both the boost and sustain pulse. The propellant shows a softening trend (lower Shore "A" Readings) from the motor centerline to the cup/liner interface. As shown on Figures 4.1-67 and 4.1-68, in Reference 8, significant local differences occur in the propellant next to the bondline. the most noticeable change occurs in the sustain pulse with marked local softening of the propellant in the release areas of the cup.

Structural Property Tests

The propellant segments from motor AHS-0036 were used to make test specimens for uniaxial and biaxial tensile tests, mini-thin tensile tests, stress relaxation tests, diametral compression tests and bondline samples for peel and tension tests.

Table 4.1-6, Reference 8 summarizes Propellant Batch 197 Acceptance data for the motor and test results on propellant from the motor after 28 months. As noted on Table 4.1-6, the properties of motor propellant were expected to be different than that of the batch acceptance cylinder. These differences were determined by dissection of six rocket motors during the DDT&E Program and the expected variations accounted for in determining the specification requirements for all propellant batches. After accounting for these expected differences, the propellant JANNAF uniaxial values for the motor are essentially the same as the unaged values.

3.1.2 Hardware Assessment

The hardware evaluation was performed on five fired field units and on one dissected field unit. The fired units were AHS-0012, AHS-0041, AHS-0070, AHS-0098 and AHS-0134. The dissect unit was AHS-0036. The evaluation consisted of removing external components and some internal components and performing a visual inspection of component condition, in accordance with the Hardware Evaluation Procedures (Reference 7).

The hardware evaluation conclusions for each of the major component areas are summarized in Appendix B. While changes were noted, none appear to contradict the design service life of five years.

3.1.3 Rocket Motor Service Life Estimate

The ballistic parameter regression analyses indicate a minimum of 81% confidence that 90% of the motor population will not reach any failure limit prior to the design service life of 5 years. While some changes were noted in hardware evaluation of the motors returned from the field, none contradict the regression analyses results and all are consistent with service usage. Although data from the dissection of motor AHS-0036 is insufficient to allow a margin of safety regression analyses, the data does show that the motor had a positive margin of safety when it was dissected. The calendar age of the oldest surveillance motor fired (AHS-0012) was 819 days (2.24 years) and the oldest dissection motor (AHS-0036) was 761 days (2.08 years). For comparison, the age difference between AHS-0012 and the oldest motor in the fleet (AHS-0001) is 56 days.

Results of the ballistic parameter regression analyses are given in Table 3-2. The parameter "boost pulse start time" ($T_{START\ 1}$) establishes the 81% confidence level as the minimum for the SRAM motor. All other ballistic parameters support confidence levels of at least 94%. Of the 45 regressions run, 42 show no trending toward a failure limit. The three regressions that show trending toward a failure limit involve the boost pulse start time. The absolute value of the trends at 2 years is about .09 seconds, which is roughly 10% of ignition start time for cold temperature firings. This trend does not represent a major concern at this time.

It can be concluded from the ballistic data analysis and hardware evaluation that the motor is aging. However, identification of the aging mechanism and rate of aging is constrained by the lack of aged data. The balance of the dissect motor data from the current surveillance program should be used to conduct the first margin of safety regression analysis.

3.2 Service Life Estimate for Ordnance Devices

The functional and non-destructive test data delineated in Section 2.0 Appendix C provides the basis for determining the service life estimates (SLE's) for each of the SRAM ordnance devices. Statistical tests conducted on the available baseline (zero time) data have determined estimates of the mean ($\bar{X}$) and standard deviation(s) of the test parameters, which will be used in developing regression trend lines, when test data from aged components becomes available.

Data for the Explosive Components (Missile Battery and Battery Gas Generator, Fin Unlock Squib, Igniter Pressure Cartridge, Missile Ejection Cartridge, and Electrical Cable Assembly Switch) was available from vendor acceptance tests for zero-time baseline, from Ogden ALC Baseline tests (except the Electrical Cable Switch Assembly), from Ogden ALC aged component tests (Missile Ejection Cartridge only) and from the 17 SAC OT&E flight tests. While data from many aged explosive components have not been generated, information from the OT&E flights indicates that all are functioning properly after nearly two years in the field.

The true failure limit for most of the ordnance devices has not been determined. Consequently, specification or acceptance test limits were used in lieu of failure limits. This substitution brought out the difficulty of establishing trends when the baseline data lies on or near the specification or acceptance limits. This led to a re-evaluation of the way to proceed. The distribution of baseline data, should also be statistically analyzed by lot, to pickup lot to lot variation and distribution. The given specification/acceptance test limits for any given test data parameter should be re-analyzed after this analysis is completed so that a more meaningful Service Life Estimate (SLE) can be accomplished with the lot to lot data bias taken into account. The steps to accomplish this task are given in Section V.

The statistical technique for predicting age-out consists of: A stepwise multiple linear regression program for determining the statistical significance for each parameter, a statistical model for determining three-dimensional parameter tolerance surfaces and conversion of the multi-dimensional information into two-dimensional plots similar to the graphic presentation in Figure 2-10.

The surveillance test parameters for estimating the service life are listed in Tables 2-4 and 3-4. Among these parameters, the data which are considered to be the controlling parameters and provide the best measure of the critical function are the critical parameters. The other parameters are considered supporting information. Table 3-4 lists the test parameters and critical test conditions which are used during the surveillance program. The types of data used in evaluation are listed in Section 2.5.B.

3.2.1 Baseline Data Analysis

This section summarizes the statistical analyses performed on the non-destructive (acceptance) test data for zero-aged components both from the contractor and Ogden ALC.

The sample sizes used are sufficiently representative of the total population to provide valid baseline data for use in initial regression analyses.

TABLE 3-4

ORDNANCE REGRESSION ANALYSES
(0 OF 140 COMPLETED)

TEST PARAMETER

COMPONENT		BRIDGE RESISTANCE	INSULATION RES.	INPUT CURRENT/TIME SR BRIDGEWIRE BURNOUT	OPERATING TIME OR TIME TO PEAK PRESSURE	PEAK PRESSURE	TIME TO FIRST PRESSURE	EJECTION VELOCITY	(TOTAL) WATER DISPLACEMENT	DRAIN COMPLETE TIME HYDRAULIC SECTIONS	DRAIN COMPLETE TIME ELECTRONIC SECTION	AUTOIGNITION TIME/TEMP	TOTAL AGING PARAMETERS	TOTAL POSSIBLE REGRESSIONS
EJECTOR CARTRIDGE		1	1	1	1	1		1					6	36
FIN UNLOCK SQUIB		1	1	1	1	1	1						3	18
IGNITER PRESSURE CARTRIDGE		1	1		1	1	1						3	15
BATTERY GAS GENERATOR	YARDNEY	1		1		1	1		1				1	5
	EAGLE PICHER	1		1					1				1	3
CABLE SWITCH ASSEMBLY			1	1								1	3	3
BATTERY POWER SUPPLY	YARDNEY		4						10	6			3	30
	EAGLE PICHER		4						10	6			3	30

TOTAL 140

The statistical treatment of the non-destructive (acceptance) functional test data is summarized in Appendix C. The analyses for each component are depicted graphically in figures in References 8 and 15. The statistical treatment of the test parameter versus each age-related parameter is plotted separately; namely, Age from Date of Manufacture, Accumulated Service Life, Total Carries, Total Flight Hours, Flight Hours Below 15,000 Feet and Installation Cycles. The Surveillance Program gas generators are subjected to simulated environments only; and for this reason, evaluation to other aging parameters are considered to be invalid.

A. Contractor Baseline Data

Evaluation of the zero-age data for all parameters, with the exception of Bridge Resistance and Insulation Resistance, indicate that the means and standard deviations were within adequate limits with respect to acceptance criteria to allow age-out determination using regression analysis. The bridge resistance data for the components are suspected to be non-normally distributed. The Quality Control procedures used in manufacturing remove those bridge circuit assemblies that do not meet specification. This could have resulted in a truncated normal distribution of the bridge resistance data. The lower three sigma limit for Insulation Resistance was observed to be significantly below the specified limit. Actual observations did not, in fact, fall below the limit, which strongly implies that this resistance is not normally distributed.

Since both the bridgewire resistance and the insulation resistance appear to be non-normally distributed, statements to the effect that 99.74% of the observations can be expected to lie within these standard deviations of the mean are invalid.

B. Ogden ALC Baseline Data

The data developed from the Ogden ALC Baseline tests is to be compared with the contractor baseline data to remove the facility bias differences in developing the Service Life Estimates for each component. These tests were also used to complete the test facility, equipment, and procedures checkout, validation, and verification requirements for all SRAM ordnance components. The Ogden ALC Baseline Tests were accomplished on all components except the Electrical Cable Switch Assembly.

Evaluation of the zero-age data for non-destructive test parameters indicate truncated non-normal distribution within the normal distribution band. Evaluation of the functional test data indicates that the means and standard deviations were within adequate limits with respect to acceptance criteria to allow age-out determination using regression analysis.

3.2.2 Service or Shelf Aged Data Analysis

This section and Appendix C Tables present the comparative statistical analyses performed on the non-destructive (acceptance) test data for the listed quantities of aged components; also the functional (lot acceptance) test data for aged missile ejection cartridge components. The data handling procedure developed is to be used as a baseline in developing Service Life Estimates for the other ordnance components. The procedure groups together the contractor and Ogden ALC baseline data and the first surveillance aged data into one group for comparison. The statistical regression treatment of each component's parameters versus each age-related parameter is plotted separately; namely, age from date of manufacture, accumulated Service Life Total Carries, Total Flight Hours, Flight Hours below 15,000 feet and Installation cycles. This regression analysis was not accomplished for any of the components because of the inability to schedule and conduct aged ordnance device testing to support SLE preparation for this year. Appendix C Tables for the missile ejection cartridge summarizes the data for the various data parameters extracted from the referenced figures with the averages, standard deviation, and chi square calculated for each parameter being presented.

The statistical analysis by attributes for the total number of cartridges fired to date was conducted on the parameters listed in Table 2-4. The averages (mean), standard deviation and CHI square were calculated. The distribution and statistical parameters assessed indicate no significant change in the ballistic performance of 24 month field aged missile ejection cartridges when compared with the baseline data.

Based on field and depot insertion and removal handling problems coupled with gas leakage past the ejector cartridge O-ring during low temperature (-65°F) firing, the Material Improvement Project OCNAN 74-0058 (YG-270) was generated to investigate these problems.

This investigation resulted in the development of a new cartridge installation and removal tool and a change in the O-Ring material from ethylene propylene to a fluorosilicone O-ring that demonstrated better low temperature properties. These changes have been verified and validated both in the field and at the depot and have solved the problems presented above.

Thus the above data supported the increase in service life of the missile ejection cartridge from one to two years.

Since testing on the other aged components was not completed in time to support the preparation of this service life estimate, the information from seventeen (17) SAC OT&E flight tests indicated all other components with nearly two years age had functioned properly and should remain at their orginal design service life estimates.

3.2.3 Hardware Assessment

The scope of hardware assessment for each ordnance component is currently limited to the content of the evaluation procedures provided in Reference 7.

The hardware assessment consists of pretest and post test inspection requirements. Pretest inspection consists of visual and dimensional checks and inspection checks for thread wear, leakage, connector damage, etc. Post test inspections include those listed above plus leakage and arcing problems. X-Ray requirements should be added if internal changes are suspected.

3.2.4 Service Life Estimate Ordnance Components

The results of statistical tests for distributional assumptions performed on the available baseline/aged data are summarized for each component in Appendix C. Functional and non-destructive test data for each variable were tested to determine the validity of the assumptions of normality. The following statistical tests (described in Reference 14) were used: (1) Chi-squared goodness of fit test for $N > 50$ (where n is the number of observations for each variable); and (2) Wilk test for $n \leq 50$.

A. Missile Ejection Cartridge

Each ejector rack firing requires the use of two cartridges and provides two data points for use as attributes in a reliability analysis. From tables based on standard statistical calculations for the number of firings presented in References 40, 41, 42 and 43, it is shown that:

(1) The two year cartridges averaging 15 months of service life exposure demonstrate a reliability of 90 percent with a 90 percent confidence level;

(2) The three year cartridges averaging 21 months service life exposure demonstrate a reliability of 90 percent with 95 percent confidence level.

The above data supports the increase in the service life of the CCU-16B Missile Ejection Cartridge from one to two years, as proposed by Ogden ALC.

B. Other Components

The inability to schedule and conduct aged ordnance device testing, during the first year's program, precluded the generation of their service life estimates. A supplemental SLE analysis and determination for each of the following ordnance devices will be made upon the completion of aged testing:

1. Igniter Pressure Cartridge
2. Fin Unlock System Pressurization Squib
3. Electrical Cable Switch Assembly
4. Battery Power Supplies (Eagle Picher/Yardney)
5. Battery Gas Generator Squibs (Eagle Picher/Yardney)

However, information from seventeen (17) SAC OT&E Flight Tests indicate that all have functioned properly after nearly two years field operational usage experience. Thus their original design service life estimates should still apply.

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SECTION IV

CONCLUSIONS

The following conclusions can be reached about the SRAM Propulsion System, and Ordnance Components, from the results of the first year of the Surveillance Program.

Motor

The service life of the propulsion subsystem should remain at its original design life of five (5) years.

There is high confidence that the SRAM AGM-69A Rocket Motor will not Age-out prior to its design service life of five (5) years.

Components

The service life of the Missile Battery and Battery Gas Generator, Fin Unlock Squib, and Igniter Pressure Cartridge should remain at their original design life of five (5) years.

The service life of the Missile Ejector Cartridge CCU-16B should be extended beyond its one (1) year original design life to two (2) years.

The service life of the Electrical Cable Assembly Switch should remain at its original design life of ten (10) years.

Total Program

Some minor degradations and aging trends have been noted but they do not contradict the findings of the 1974 SLE.

Identification of specific aging mechanisms and rates of observed degradations cannot be obtained with the limited amount of data available.

The Surveillance Program should be continued as planned to obtain more data and investigate known concerns in more detail.

The technical orders 11A15-1-327 and 21M-AGM69A-06 should be revised in accordance with Table 4-1 for the SRAM components.

Evaluation of zero-age data for all parameters for all ordnance components indicates that the means and standard deviations are within adequate limits with respect to the acceptance criteria to allow age-out determination using regression analysis with the exceptions listed below. These exceptions (parameters) appear to be non-normally distributed. Thus statements to the effect that 99.74% of the observations can be expected to lie within these standard devia-

TABLE 4-1

PROPOSED REVISIONS TO T.O. 11A15-1-327 AND 21M-AGM69A-06

ITEM	CURRENT LIFE (YEARS) TOTAL	CURRENT LIFE (YEARS) SHELF	CURRENT LIFE (YEARS) SERVICE	REVISED LIFE (YEARS) TOTAL	REVISED LIFE (YEARS) SHELF	REVISED LIFE (YEARS) SERVICE
Assembled (tactical) AGM-69A Missile						
Rocket Motor SR75-LP-1 (Lockheed Propulsion Co., P/N 250777-505)	5	5	5	NO CHANGE		
Igniter MK22 Mod 0, P/N 3953-1						
Fin Unlock Subsystem Gas Generator Assembly (Holex Inc., P/N 7888-2)	5	5	5	NO CHANGE		
Cold Gas Driven Hydraulic Accumulator System Igniter Assembly Pressure Cartridge (Holex, Inc., P/N 9393-1)	5	5	5	NO CHANGE		
Cold Gas Driven Hydraulic Accumulator System Helium Storage Bottle (Walter Kidde, P/N 895271-01)	5	5	5	NO CHANGE		
Missile Ejection Cartridge CCU-16/B (OEA, Inc., P/N 2151800-0)	5 [1]	5 [1]	1.0 [1]	5 [1]	5 [1]	2.0 [1]
Power Supply Battery PP-6268/ASQ (Eagle-Picher, P/N GAP-4367-11-3)	5	5	5	NO CHANGE		
Power Supply Battery PP-6268/ASQ (Yardney, P/N P-5560-10-1)	5	5	5	NO CHANGE		
Electrical Cable Assembly-Switch HRU-825/A (Unidynamics, P/N 50-2200-111-19)	10	10	10	NO CHANGE		
Command Destruct Safe and Arm Device (Consolidated Controls Corp., P/N 71856-101)	5	5	5	NO CHANGE		
Explosive Transfer Assembly (Thiokol Chemical Corp., P/N E24616-04 or E24616-06)	5	5	5	NO CHANGE		
Linear Shaped Charge (Destruct) (Thiokol Chem. Corp., P/N E24817-01 and E24817-02)	5	5	5	NO CHANGE		
	[1] Or 1.0 year after removal from storage container.			[1] Or 2.0 years after removal from storage container.		

tions of the mean are invalid. The quality control procedures used in manufacturing remove those sub-components or subassemblies (i.e. Bridgewire circuits) that do not meet specification. This could have resulted in non-normal distributions such as truncated normal, bimodal, or log-normally distributions. In some cases the lower three sigma limits for a parameter was observed to be significantly below the specified limit, while actual observations did not, in fact, fall below the limits, whuch strongly implies the parameter is not normally distributed. The non-normal distribution exceptions are as follows:

a. Missile Ejection Cartridge - Bridgewire and Insulation Resistance

b. Igniter Pressure Cartridge - Bridgewire and Insulation Resistance

c. Fin Unlock Squib - Functional Data and Insulation Resistance

d. Eagle Picher Battery - Insulation Resistance

e. Yardney Battery - Insulation and Bridgewire Resistance

f. Yardney Battery Gas Generators - Insulation and Bridgewire Resistance

SECTION V

RECOMMENDATION

The Surveillance Program should continue along the guidelines established in Reference 5, the SRAM Explosive Component Surveillance Program Implementation Plan.

More emphasis should be placed on the dissection portion of the program to gain more information on the failure mechanism of the SRAM motor, and to investigate specific areas of concern in more detail. Due consideration should also be given to change the static fire to dissection ratio from 5 to 2 to 4 to 3 because of the high number of planned SAC Operational Flight Tests per year.

The ballistic performance data should be compared with the bands of previous experience to determine whether any parameter exceeds those bands and is presented in subsequent SLE.

The magnitude of short duration pressure excursions (blips) on chamber pressure traces and their frequency of occurrence should be evaluated in future SLEs as a possible age-out parameter.

The evaluation of sustain igniter gaps as determined from motor x-rays should be continued. Ogden ALC should attempt to obtain samples of gas from the sustain igniters of future dissect motors.

Consideration should be given to conducting ultrasonic inspection of motor nozzles prior to firing to establish the bonding characteristics of aged nozzles.

Inspection of the external condition of the aged motors should be conducted prior to delivery to the test area. This will allow a more definitive determination of the effect of field exposure conditions versus effects resulting from firing conditioning.

The balance of the dissect motor data from the current surveillance program should be used to conduct the first margin of safety regression analysis. It is further recommended that this data be used to confirm the observations made relative to the differences between the boost and sustain data from the motor. Differences were noted in the following areas:

a. Strand burn rate distribution
b. Peel failure mode and boost versus sustain peel values
c. Shore "A" hardness

d. Uniaxial versus biaxial data relationship
e. Mini-thin boost versus sustain
f. Stress relaxation shift
g. Relaxation modulus - boost versus sustain
h. Bulk modulus.

Incorporate contractor provided standard procedures into 2K-XXXXX Technical Orders to evaluate each rocket motor and explosive component that is returned to the depot for repair or other reason for possible use in the surveillance program. These articles may be good candidates for providing data for the surveillance program.

Include a test and/or hardware evaluation of the rocket motor initiators removed from dissection motors and other available sources.

Do not incude dynamic resistance testing of SRAM Electro-Explosive Devices (EEDs) as a part of the surveillance test program. The dynamic resistance test is a sensitive non-destructive test for evaluation of the electro-thermal characteristics of the bridge circuit and can provide an additional means for evaluating the effects of aging on the EEDs but it tends to degrade the Bridgewire and thus may give erroneous readings on the functional component tests. The baseline dynamic resistance data for evaluating the surveillance test results was not generated for each type of ordnance device.

Review the rocket motor propellant physical property test program for test scope and objectives, as additional test data becomes available, to substantiate the baseline data and to provide for more valid technical decisions.

Incor[illegible]ate evaluation tests for the components and motor chamber areas [illegible]fied as critical in the "age sensitive item assessment", Refer[illegible] Tests and inspection for corrosion/stress corrosion in the cas[illegible]g areas would be responsive to the critical item assessment.

Obtain from SAC or get on the distribution list for the SACM 65-2 Aerospace Vehicle Movement Report RCS: log-MM(AR) 1703, project; SACM 2-191 to provide a shipping notice to OOAMA recording missile/booster transfer from one Air Force base to another. This is recommended to maintain a cumulative location history of SRAM missiles.

The developed hardware evaluation requirements/procedures for pre-test and post-test inspection of surveillance hardware should be incorporated into 2K series technical orders and followed for all field motor static firing and dissection motors and all ordnance components (Reference 7).

The probability distributions of the parameters should be determined and, where appropriate, tolerance bands for non-normal distributions and lot to lot variations therein snould be developed. Also, the reasons for the correlations between serial number or lot number and functional parameters should be determined and appropriate analysis procedures developed.

Recommendations for future ordnance component evaluations are as follows:

a. Conduct a test and evaluation program on the related element of the SRAM system to determine a true functioning performance limit for the ordnance device.

b. Substitute the limit obtained by (a) for the specification/acceptance limit in conducting statistical regression analyses to predict aging trends in determining the SLE.

c. Prior to proceeding, the value of the parameter used in developing the service life estimate for the device should be assessed to justify initiation of a test and evaluation program, or to delete the use of this parameter from the variables analysis.

d. Should the parameters be determined as non-critical in developing the service life estimate, the surveillance test results (for the parameter only) should be used as attribute data in making reliability and confidence levels statements for the device.

e. Conduct lot to lot statistical variation analysis on all the small components baseline data since all lots were pooled and this analysis may provide some test data bias removal capability.

Recommendations for refinement of existing SRAM Surveillance Program procedures are as follows:

a. Statistical analysis

1. The use of one-sided tolerance curves for the component parameters having one-sided failure limits.

2. The use of probability distributions rather than worst case values for the critical conditions such as propellant burn-rate and component firing temperature.

b. Since aged data was available in time for service life regression analysis for only one of the small ordnance devices, a quick-look analysis of the baseline data revealed several potential problems in analyzing variables data for the ordnance devices. These problems are:

1. Some of the data is not normally distributed and new procedures will be required for handling this data.

2. The standard deviations for some component parameters is dependent on the component test conditions. Techniques will be required for developing tolerance curves for this type of data.

An area which should be investigated for future service life analysis is the effect of different base environments on component service life. It is conceivable that missile components stored in different climates will age differently. Procedures should be developed to determine whether component service life is dependent on climate and, if so, then service life estimation procedures which include climate effects should be developed.

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b. LATP 270 — Lot Sample Acceptance Test Procedures for Battery Dual Section; Eagle Picher Industries

c. ATP 271 — Acceptance Test Procedures for Battery, Dual Section; Eagle Picher Industries

38. Boeing Specification 21A14255, Surveillance Test Set, Battery Gas Generators; dated 2 May 1973

a. QTP 116 — Qualification Test Procedure for GG 201-3 (31-00-013-0) Gas Generator; Eagle Picher Industries

b. LATP 287 — Lot Acceptance Test Procedure for GG 220 (YEC P/N P-5580); Eagle Picher Industries, Joplin, Missouri

c. ATP 190 — Acceptance Test Procedure for GG 201-3 (31-00-013-2); Eagle Picher Industries, Joplin, Missouri

39. Minutes of the SRAM Surveillance Program Working Group Meeting, at The Boeing Company, Seattle, Washington, dated 7-10 May 1974

40. Boeing Letter #2-5340-5000-064 dated 2 July 1974 Contract F33657-73-C-0734 (FY 74 SRAM Production) SRAM Explosive Component Surveillance Program, Missile Ejection Cartridge CCU-16/B Service Life Estimate

41. Letter, Surveillance Test, Missile Ejection Cartridge CCU-16/B Department of the Air Force, Headquarters; Ogden Air Logistics Center (AFLC) (MME) R. W. Goodfellow to ASD/YGE (Major C. E. Stanbery); dated May 23, 1974; Test Project M42245C

42. Letter, Surveillance Test, Missile Ejection Cartridge CCU-16/B Department of the Air Force Headquarters, Ogden Air Logistics Center (AFLC) (MMEC) Ray Holmes to ASD/YGE (Major C. E. Stanbery); dated March 25, 1974; Test Project M41834C.

43. Boeing Letter #2-5340-5000-015 dated 27 November 1973, Contract F33657-71-C-0918 (FY 72 SRAM Production) SRAM Explosive Component Surveillance Program Missile Ejector Cartridge CCU-16/B

44. Letter, Surveillance Test, Igniter Pressure Cartridge, Department of the Air Force, Headquarters, Ogden Air Logistics Center (AFLC) (MMEC) Ray Holmes to ASD/YGE (Major Stanbery); dated March 20, 1974; Test Project M41835C

45. Letter, Surveillance Test, Fin Unlock Squib, Department of the Air Force, Headquarters, Ogden Air Logistics Center (AFLC) (MMEC) Ray Holmes to ASD/YGE (Major Stanbery); dated March 20, 1974; Test Project M41836C.

46. Letter, Surveillance Test, Battery Power Supplies, Department of the Air Force, Headquarters, Ogden Air Logistics Center (AFLC) (MME) R. W. Goodfellow to ASD/YGE (Major Stanbery); dated 17 June 1974; Test Project M42389C

47. Letter, Statistical Evaluation of AGM-69A Gas Generator Test Data, Department of the Air Force, Headquarters, Ogden Air Logistics Center (AFLC) (MMER) to Ogden ALC/MMECL; dated 18 July 1973; Test Project M31892/M31893

48. Letter, Surveillance Test, Battery Gas Generator P/N GG201-3, Department of the Air Force, Headquarters, Ogden Air Logistics Center (AFLC) (MME) R. W. Goodfellow to ASD/YGE (Major Stanbery); dated 24 April 1974; Test Project M31892C

49. Letter, Surveillance Test, Battery Gas Generator P/N GG 220, Department of the Air Force, Headquarters, Ogden Air Logistics Center (AFLC) (MME) R. W. Goodfellow to ASD/YGE (Major Stanbery); dated 5 June 1974; Test Project M31893C.

50. Letter, Surveillance Test, Igniter Pressure Cartridge, P/N 9393-1, Department of the Air Force, Headquarters, Ogden Air Logistics Center (AFLC) (MME) R. W. Goodfellow to ASD/YGE (Major Stanbery); dated 22 November 1974, Test Project M41834C Tested 9 September 1974.

51. Letter, Surveillance Test, Fin Unlock Squib P/N 7888-2, Department of the Air Force, Headquarters, Ogden Air Logistics Center (AFLC) (MME) R. W. Goodfellow to ASD/YGE (Major Stanbery); dated 21 November 1974, Test Project M41836C Tested 9 September 1974.

52. Boeing Letter #2-7712-0074-311 dated 21 October 1974, Contract F33657-73-C-0734 (SRAM FY74 Production), Continuation of Contractor Technical Services and Planning in Support of the SRAM Explosive Component Surveillance Program, Tests on Igniter Pressure Cartridge and Fin Unlock Squib Conducted August 19, 20, 21 and 9 September 1974.

53. Boeing Letter #2-7912-0019-139 dated 3 September 1974, Contract F33657-73-C-0734 (FY74 SRAM Production), Material Improvement Project (MIP) OCNAN 74-0058, YG-270, C.O. P00175 FB-111 Missile Ejector Malfunction, WUC 95X00, AGM-69A.

54. ASD/YS69E MIP Investigation Analysis Report, dated 25 October 1974, MIP OCNAN 74-0058, YG-270, MAU-140/A Missile Ejector Malfunctions.

55. Boeing Letter #2-5340-5010-038, Trip Report - Ogden ALC, Utah, To Attend SRAM Surveillance Program Working Group Meeting, November 5-7, 1974 (Ordnance Devices).

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